NASA TECHNICAL
MEMORANDUM

NASA TM X-58055
January 1971

SPACE PROGRAM BENEFITS

By Frederick A. Zito

A Thesis Presented to the Faculty of the
Graduate School of New York University
In Partial Fulfillment of
the Requirements for the Degree
Master of Business Administration

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

PREFACE

Worldwide television and other news coverage of space flight missions, manned and unmanned, has brought U.S. space achievements before the largest audience in history. The benefits and impact of the U.S. space program on society are just beginning to be understood. The spectacular achievements in space have overshadowed the less dramatic but equally important story of the many benefits the country is realizing from our space program. This thesis will discuss not only scientific and technological benefits but the impact space is having on our society, our technology, our industrial economy and our planetary environment.

The question of benefits to the economy from the space program is a very important one, especially to the Congress and to NASA, for justifying the annual NASA space budgets. Many documents are available on the subject which include government reports, speeches, studies and editorials. The most applicable of these documents have been researched and utilized in the preparation of this thesis. Acknowledgement is given to the following persons for invaluable assistance in locating and obtaining reference material and for guidance in the utilization of that material:

Mr. Joseph M. Carlson,	NASA Office of Technology Utilization, Washington, D.C.
Mr. Richard Dunne,	Assistant Director, Public Affairs Office for Space, Grumman Aerospace Corporation, Bethpage, N.Y.
Mr. Paul S. Feinstein,	Chief, NASA Information Services Branch, Washington, D.C.
Dr. Arie Y. Lewin	Associate Professor of Management, New York University, Graduate School of Business Administration, Thesis Advisor
Mr. Anthony L. Liccardi,	Assistant Manager, NASA Resident Office at Grumman
Mr. Bertram A. Mulcahy,	NASA Headquarters, Office of Congressional Affairs, Washington, D.C.
Mr. Joseph A. Riley,	Associate Business Consultant, State of N.Y. Washington Office
Mr. Daniel F. Ruge,	Director, State of N.Y. Washington Office

Frederick A. Zito

December 18, 1970

Frederick A. Zito

TABLE OF CONTENTS

CHAPTER I

WHAT RETURN IS THE UNITED STATES RECEIVING FROM THE SPACE PROGRAM

Introduction

Space Flight has been the subject of many fictional stories dating back into antiquity. Some of the better known examples include the story of the Greek Artisan Daedalus and his son Icarus whose feather wings held together by wax came apart as they flew too close to the heat of the sun. Jules Verne's prophetic story of a rocket trip to the Moon is also illustrative of the fact that many persons have correctly predicted that mankind would someday embark on a program of Space Flight.

This fascination with the possibilities of Space Flight does not unanimously extend itself to the layman when it becomes a matter of deciding whether tax money should be spent for travel to the Moon and other places. For the most part, the public who are also the persons financing the national space effort cannot understand why billions of dollars are being spent for space ventures when so much remains to be done on Earth.

Mr. Dale Myers, Associate Administrator for Manned Space Flight, in a November 1970 speech and press conference before members of the Long Island Association in Garden City, N.Y. made some positive comments about the benefits of the space program;[1]

> The Soviet rate of launching is increasing even while ours /American/ is decreasing.
>
> The U.S. is just about at rock bottom /$3.6 billion for NASA, $6 billion total for U.S. for 1970/, as far as funding for space is concerned. If anything, more funds should be funneled into the space effort - and for the very practical reason that it has paid off.

---

[1] Grumman Plane News Article, Myers Sees U.S. Approaching Critical Point in Space Budgets, Vol. 29, No. 21, Bethpage, N.Y., Nov. 30, 1970, p. 3.

> Throughout our industry we see thousands of new techniques, new products, and a great number of whole new companies formed to provide these goods and services.

Dale Myers mentioned some yields from previous American space efforts:

> A very favorable balance of trade in aerospace and computer sales abroad, a great advance in the techniques of management of very large technological enterprises, satellite communications, international TV, new computer controlled transmission systems world-wide in scope, improved weather forecasting, medical treatment and hospital automation and education techniques.

Mr. Myers saw ecology as a fruitful area of study;

> The space age has enabled man to examine and measure the earth as an entire planet, avoiding the laborious and often the impossible tasks of assembling bits and pieces of information simultaneously from all over the surface. Probably the most important contribution that can be made by observations from space is to determine whether the basic cycles of the earth's biosphere are being disturbed by human activity, and if so, how much.

There are many answers to the questions raised about the why and wherefore of the Space Program. This thesis will attempt to point out the benefits of the Space research. In general, it can be stated that most people have an exaggerated idea of the proportion of national money spent on Space. For example, from 1960 to 1969, a total of $49.7 billion was spent on the American military and civilian space effort with an annual average expenditure of $5 billion. This thesis will be limited to the civilian effort except in those instances where it is necessary to relate one program to the other. The figures for the civilian effort are an average of $3.56 billion spent in each of the 10 years between 1960 and 1969. The $49.7 billion represents four percent of all federal tax collections for the decade or less than ½ of 1% of the gross national product.

To put these expenditures for space work into perspective, some comparative spending figures by Americans for the same time period are presented. Americans spent $12.3 billion a year for alcoholic beverages; $7.9 billion for tobacco; 5.3 billion a year for radios, TV's, records; $5.2 billion a year for shoes and other footwear[2]. All of these expenditures equal or substantially exceed the space expenditures.

The September 10 issue of Long Island's daily newspaper carried this headline on the back page; "Rover Eats High on the Hog". The article stated that Americans spent $1 billion in 1969 feeding their 25 million dogs and 20 million cats. The forecast for 1970 was $1.16 billion and $1.5 billion by 1975. This expenditure which is constantly rising is up from a $600 million expenditure in 1965. The article closes with the cryptic statement that; "It is perhaps a sign of the times that the U.S. consumers now spend more annually on prepared pet foods than they do for canned baby foods".[3] The article could also have said that Americans spend only slightly more than three times as much on the civilian space effort which in 1969 reached its planned climax with the manned landing on the Moon.

An analysis of these comparative figures would seem to indicate that the space budget is not the crushing financial burden that many people think it is or, in fact, is not a burden at all. A smoker or a drinker would certainly not feel that his expenditures for cigarettes or highballs are adversely affecting his personal finances in a significant manner. Considering the figures presented, can the lesser expenditure for the space work be considered excessively burdensome to the country or to individual taxpayers? This is a question this thesis will attempt to answer.

In addition to the argument of direct cost, detractors of the space program make use of the rationale of using funds allocated for space for more necessary problems at home, such as cancer research, building schools, feeding the poor, etc. It is an established fact that all of these domestic social problems have been with us for

[2] World Reaction to Moon Flight, U.S. News and World Report, August 4, 1969, p. 27.

[3] Clarence Newman, "Rover Eats High on the Hog", Newsday, September 10, 1970, p. 96, business section.

years. There is no guarantee nor is it likely that the money diverted from Space Research would be allocated for social problems. Or, if the money were reallocated, that it would make any appreciable difference in the outcome of these laudable social programs.

Dr. Wernher Von Braun succinctly stated this same sentiment in 1964:

> I do not believe that if this [space] budget were cut any substantial increase would accrue to these other programs - [defense, agriculture and welfare] programs which I incidentally consider very worthwhile. Based on my own personal experiences before congressional committees, I do not believe that these annual appropriations are solely the result of fiscal finagling with figures, with funds being taken from this agency and applied to that agency, like some act carried out under a master plan. I believe the approach taken by our elected officials is one in which each program must stand or fall on its own merits, as viewed by the American voter.[4]

In the area of technological innovations, Dr. George E. Mueller, former Associate Administrator for Manned Space Flight for NASA, said this in a recent speech: [The thesis will discuss these innovations and their significance in greater detail.]

> Over 2500 technological innovations have been directly attributed to the space program, including new alloys, miniaturized electronic components, non-flammable cloth, biomedical equipment of many types, new food treatment methods, inorganic paints, new flexible pipe for fluid conveyance, greatly improved batteries, micro miniature parts.[5]

---

[4]Wernher Von Braun, "The Future of Space", Proceedings of the Fourth National Conference on the Peaceful Uses of Space held in Boston, Massachusetts, April 29-May 1, 1964, National Aeronautics and Space Administration document SP51, Scientific and Technical Information Division, Washington, D. C., p. 73.

[5]Address by Dr. George E. Mueller, Associate Administrator for Manned Space Flight, National Aeronautics and Space Administration made before the New York Society of Security Analysts, New York City, Jan. 28, 1969, p. 11.

In the area of economic benefits, Dr. Mueller had this to say in the same speech: /The thesis will cover the economic area in greater detail./

> Skilled workers and scientists have been employed in our space program, with an annual payroll that peaked at 2.7 billion in 1966. This money was poured back into the economy for goods and services in every state in the nation. For we are not, as you well know, spending our money in space or on the Moon -- It is all being spent right here on Frank Borman's 'Good Earth'.[6]

Space exploration has always been compared with other voyages of discovery and especially the discovery of America. Mr. J. Lynn Helms, Vice President of the Aerospace Systems Group, in a 1967 speech stated this:

> ...The Queen of Spain mortgaged her jewels to launch a small expedition to explore a new world, and Spanish galleons subsequently ruled the seas for a hundred years.[7]

The public wants to know (and consequently so does the Congress) what the benefits of the Space Program are. In addition to the many economic and technological benefits that have accrued, there are the international benefits of increased national prestige. This technological triumph has significantly increased the U.S. scientific stature in the eyes of the people of many nations of the world, friend and foe alike.

Arthur C. Clarke noted science fiction writer said in one of his books:

> The road to the stars has been discovered none too soon. Civilization cannot exist without new frontiers. It needs them both physically and spiritually.

---

[6] Ibid., p. 24.

[7] Speech, The Space Program, A Citizens Return on Investment by J. Lynn Helms, Vice President, Aerospace Systems Group, The Bendix Corporation, presented at Rotary International during the University of Michigan's Sesquicentennial Celebration, Sept. 13, 1967, Ann Arbor, Michigan.

What Some People Say about the Broad Values of Space Research

Many persons and organizations of prominence consider the overriding significance of the space age as another epochal extension of mankind's horizon, from the earth to the stars. The first manned landing on the moon is considered by many to be a momentous historical event which may change man's course of destiny and perhaps determine the leadership of societies on earth for generations to come.

The 59 page report cited above[8] was compiled by Mr. Philip P. Dickinson of the technical staff of the Committee on Science and Astronautics. The material in the report was based on material gathered from sources in government, industry and the press and it includes speeches in support of the space program from an impressive list of United States Congressmen.

Some quotations printed in the report are reprinted herein: President Nixon - "In the year 2000 we on this earth will have visited new worlds where there will be a form of life" (to a group of students at the White House in July 1969).

President Johnson - "We are reaching for the stars...we will not abandon our dream....Future generations, looking back at our incredible decade, will be unanimous in their belief that the treasure we have dedicated to sending man to explore the stars was the most significant investment ever made by any people"(at the Manned Spacecraft Center at Houston in May 1968).

Hugh Dryden, former Deputy Administrator of the National Aeronautics and Space Administration, in an article entitled "The Politics of Space Cooperation" in the Futurist of October 1969 said "Some social scientists have speculated that the exploration of space might become in time a substitute for war. Our hope would be that the absorption of energies, resources, imagination, and agressiveness in the exploration of space might contribute to the maintenance of peace".

---

[8] Report of the Committee on Science and Astronautics, U.S. House of Representatives, Ninety-first Congress, Second Session, For the Benefit of All Mankind - A Survey of the Practical Returns From Space Investment Sept. 14, 1970, p.2.

Karl G. Harr, Jr., President of Aerospace Industries Association - "There is a direct and beneficial relationship between our space effort and the strength and growth of our overall economy, our standing among the peoples and nations of the world, our national survival and our capacity to deal effectively with all national needs."

<u>What the Press Says about the Broad Values of Space Research</u>

The Washington Post in an article by Haynes Johnson in the issue of April 9, 1970 said "Some intimately associated with America's space effort see its greatest achievement as a state of mind....The space program is the cleared proof that a nation can set a difficult goal and carry it out. If it has done nothing else, it has demonstrated how America can, when it wants to, marshall its talent, commit its treasure, gain public support, and achieve its task."

Aviation Week and Space Technology in an editorial by Robert Hatz in the issue of June 22, 1970 said, "The Apollo program stands unique in the history of man as a monolithic blend of technology and management to achieve an unprecedented human goal."

Air Force and Space Digest in an article by James J. Haggerty in the issue of February 1970 said, "The U.S. space investment is already paying handsome dividends....which include new techniques, new processes, new services, new products, even new companies formed to exploit the wealth of technical know-how accumulated in 12 years of concentrated space effort....Substantial as it is, the current flow from the wellspring of space technology is only a trickle compared with the flood to come....within the decade just starting."

Fortune magazine in an article by Tom Alexander in the issue of July 1969 said, "The really significant fallout from the strains, traumas, and endless experimentation of Project Apollo has been of a sociological rather than a technological nature; techniques for directing the massed endeavors of scores of thousands of minds in a closeknit, mutually enhancive combination of government, university, and private industry. This is potentially the most powerful tool in man's history." This Fortune article by Alexander will be discussed at greather length in Chapter III of this thesis under management benefits.

Some Public Testimony about the Broad Values of Space Research

Dr. Glenn T. Seaborg, Chairman, Atomic Energy Commission in a statement on July 24, 1970 said, "Space Exploration, rather than being in opposition to meeting needs on Earth, is in fact part of a search for knowledge that is indispensable for meeting those needs...."

The National Academy of Sciences in a report titled, "Useful Applications of Earth Oriented Satellites" said, "Satellites are our newest natural resource....Benefits, in some instances, are predictably great; in others they may be matters of either judgment or reasonable surmise. What is certain is that space technology can be exploited for human good."

The Stanford Research Institute in a publication titled, "The Benefits of the National Space Program and Their Application and Understanding by the American Public" in March of 1969 said, "Our Space explorers have developed tools that they have passed over to other men. They have developed materials to be used by other builders. They have evolved techniques to challenge creative minds."

Statement by Dick Gregory, Comedian and Black Activist [9]

> I've always felt that we as a nation are rich enough to get to the moon and solve the problem of poverty too. I don't agree with the people who say we should spend the money to go to the moon on poverty instead. We could do both. What happened to poverty before we had a space program? What happened to poverty before we had a Vietnam war?

Recently Representative James W. Symington of Missouri mentioned a satellite use for a problem of worldwide concern: [10]

> It [earth resources satellite] will monitor the oceans as well, and warn man against the depredations of his oil and fishing industries which disturb the life cycle of the sea, possible even jeopardizing the orderly process of oceanic photosynthesis from which most of our oxygen is derived.

---

[9] Dick Gregory, New York Daily News, July 1969 Special Issue commemorating the first Manned Lunar Landing.

[10] Speech by Representative James W. Symington, Missouri, Member of the Committee on Science and Astronautics, on April 23, 1970 on the subject of Space Program Benefits.

CHAPTER II

TECHNOLOGICAL BENEFITS

The space program has been credited with generating and stimulating technological development and scientific knowledge and there have been unprecedented requirements for precision and reliability on the components of spacecraft.

Recently a letter was received by Dr. Ernst Stuhlinger, Associate Director of Science at the NASA Marshall Space Flight Center, Huntsville. The letter was written by Sister Mary Jucunda, a nun who works among starving natives of Zambia, Africa. In her letter Sister Jucunda asked Dr. Stuhlinger how he could suggest the expenditures of billions of dollars for a voyage to Mars, at a time when many children on this earth are starving to death. Dr. Stuhlinger wrote a lengthy answer in which he thanked Sister Jucunda and expressed great admiration for their work.

Dr. Stuhlinger stated that he had known of famished children long before he knew that a voyage to the planet Mars was technically feasible but that he felt the space program would contribute much to the solution of these grave problems we are facing here on earth.

Before trying to describe in more detail how our space program is contributing to the solution of our earthly problems, he related an interesting true story which he thought would support his argument. He told of a benign count in a small town in Germany about 400 years ago who gave a large part of his income to the poor of the town. The count also supported a man who was working on a glass lens apparatus that had magnification powers. The man was invited to become a member of the count's household so he could devote full time to the development and perfection of his optical gadget.

The townspeople became angry at this use of the count's money. They were suffering from the plague and felt the man was wasting his time on a useless hobby. The count remained firm.

> "I give you as much as I can afford", he said, "but I will also support this man and his work because I know that someday something will come out of it."[11]
>
> The microscope is what finally came out of this work and similar work done by others at other places. It is well known that the microscope has contributed more than any other invention to the progress of medicine and that the elimination of the plague and many other contagious diseases from most parts of the world is largely a result of studies which the microscope made possible.[12]

The count, by retaining some of his money for research, contributed far more to the relief of human suffering than he could have contributed by giving all of his money to the poor. The situation with our national budget today is similar in many respects. The annual budget this year is about $200 billion and about 1.6% is allocated for space exploration.

Dr. Stuhlinger then addressed himself specifically to the hunger problem cited by Sister Jucunda.

> Basic to the hunger problem are two functions: The production of food and the distribution of food. Food production by agriculture, cattle ranching, ocean fishing and other large scale operations is efficient in some parts of the world, but drastically deficient in many others.
>
> For example, large areas of land could be utilized better if efficient methods of watershed control, fertilizer use, weather forecasting, fertility assessment, plantation programming, field selection, planting habits, timing of cultivation, crop survey and harvest planting were applied.
>
> The best tool for the improvement of all these functions, undoubtedly, is the artificial earth satellite. Circling the globe at a high altitude, it can screen wide areas of land within a short time, it can observe and measure a large variety of factors indicating the status and conditions of crops, soils, droughts, rainfall, snow cover,

---

[11] Marshall Space Flight Center Newspaper, Huntsville, Alabama, Why Explore Space, Dr. Ernst Stuhlinger, Summer 1970.

[12] Huntsville News, Huntsville, Alabama, The Microscope Came From a 'useless hobby', Sue Butler, Monday August 17, 1970.

> etc., and it can radio this information to ground stations for appropriate use.
>
> It has been estimated that even a modest system of earth satellites equipped with earth resource sensors, working within a program for worldwide agricultural improvement, will increase the yearly crops by an equivalent of many billions of dollars.[13]

Dr. Stuhlinger then stated that the distribution of food to the needy was a completely different problem and not so much one of shipping volume but of international cooperation. He felt that efficient relief from hunger would not come before the boundaries between nations became less dividing than they were today.

Dr. Stuhlinger continued that higher food production through survey and assessment from orbit, and better food distribution through improved international relations, are only two examples of how profoundly the space program will impact life on earth.

In Dr. Stuhlinger's letter he mentioned and discussed two other examples of benefits of space research: stimulation of technological development and generation of scientific knowledge.

> The requirements for high precision and for extreme reliability which must be imposed upon the components of a moon traveling spacecraft are entirely unprecedented in the history of engineering.
>
> The development of systems which meet these severe requirements has provided us a unique opportunity to find new materials and methods, to invent better technical systems, to improve manufacturing procedures, to lengthen the lifetime of instruments and even to discover new laws of nature.
>
> All this newly acquired technical knowledge is also available for applications to earthbound technologies. Every year, about a thousand technical innovations generated in the space program find their ways into our earthly technology where they lead to better kitchen appliances and farm equipment, better sewing machines and radios, better ships and airplanes, better weather forecasting and storm warning, better communications, better medical instruments, better utensils and tools for every day use.

---

[13] Stuhlinger, op.cit.

> As a stimulant and catalyst for the development of new technologies, and for research in the basic sciences, it is unparalleled by any other activity. In this respect, we may even say that the space program is taking over a function which for three or four thousands years has been the sad prerogative of wars.
>
> How much human suffering can be avoided if nations, instead of competing with their bomb-dropping fleets of airplanes and rockets, compete with their moon-traveling space ships! This competition is full of promise for brilliant victories, but it leaves no room for the bitter fate of the vanquished which breeds nothing but revenge and new wars.
>
> The photograph which I enclose with this letter shows a view of our earth as seen from Apollo 8 when it orbited the moon at Christmas, 1968.
>
> Of all the many wonderful results of the space program so far, this picture may be the most important one.
>
> It opened our eyes to the fact that our earth is a beautiful and most precious island in an unlimited void, and that there is no other place for us to live but the thin surface layer of our planet, bordered by the bleak nothingness of space.
>
> Never before did so many people recognize how limited our earth really is, and how perilous it would be to tamper with its ecological balance.
>
> Ever since this picture was first published, voices have become louder and louder warning of the grave problems that confront man in our times: pollution, hunger, poverty, urban living, food production, water control, overpopulation.[14]

NASA recently reported[15] on their activities to save the corn crop in Indiana in conjunction with an effort by Purdue University. The project seeks to determine whether the current corn blight infestation can be spotted from sensing devices carried aboard aircraft.

---

[14] Stuhlinger, op. cit.

[15] NASA Aids in Effort to Save Corn Crop, Roundup, NASA Manned Spacecraft Center, Houston, Texas, Sept. 11, 1970, Vol. 9 No. 23, p. 1.

First data analyzed shows that the fungus infection, "southern leaf blight", can be identified from aircraft in its severe stage and it appears to show up at earlier stages as well.

Color photographs as well as multispectral scanner pictures and data show what photo interpreters call "signature keys" to the crop disease. That is, various gradations in color in the photos appear only when the blight is present.

Successful identification can be important to agriculture in the future because it promises that remote sensing can give farmers warning of crop diseases approaching or even present in their fields before they are aware of it.

Another promising aspect is that large areas of farmland may be quickly and accurately surveyed from the air and probably, in the future, by satellite. The knowledge gained (type of crop in each field, size of the field, crop vigor, detection of any damaging agents and eventually yield-per-acre) may be used regionally and nationally on a timely basis by private and government interests to help keep the supply of essential foods or fibers in balance with damand.

In the same periodical[16] NASA, in a cooperative effort with Oregon State University, also reported on research which may prove helpful in catching the elusive fast-swimming albacore tuna. NASA used a converted Lockheed Electra NP3A Aircraft to fly more than 11,000 miles over the Pacific collecting data.

The aircraft equipped with sophisticated electronic gear, traced a zigzag path for seven days 1,500 feet above the surface of the ocean recording sea temperatures and water color differences. The research attempts to relate in a systematic way the factors that determine whether albacore will be present in a particular area and just how abundant they will be.

Hundreds of the 750 fishermen which comprise the Oregon tuna fleet have cooperated in this effort with NASA and OSU. Each day the fishermen write in their logs the sea temperature, water color, weather, and most importantly, the number and location of each albacore catch.

---

[16] Manned Spacecraft Center Aircraft Searches for Clues to Tuna Fish Grounds, <u>Roundup</u>, NASA Manned Spacecraft Center, Houston, Texas, Sept. 11, 1970, Vol 9 No. 23, p. 4.

For the present the research attempts to help the fishermen by gathering information about factors that may affect the fishery. It leaves to the individual fisherman the judgment about where and when he should fish. For example, fishermen know that in the waters off the Pacific Northwest they'll find albacore in the water that is between 58 and 65 degrees farenheit.

Throughout the documents that were read during the research for this thesis was woven the same underlying theme of where the money is spent. Mr. Helms, Vice President of the Aerospace Systems Group of the Bendix Corp., answered this rhetorical question succinctly when he stated:

> Obviously we spend no money in space. We only spend money on the surface of the Earth and primarily in the United States, and it contributes to our gross national product.[17]

NASA has been criticized for not having a more effective public relations information program which tells the public about the benefits accruing from the space effort. Congressman Karth of Minnesota said on this point:

> You've got to go where the people are, you've got to convince them that what we are doing is worthwhile, you've got to show them that you're going to give them a return with interest for their tax dollars....There is a vitally important story to be told, a story that demonstrates and sells value, real value.[18]

From the time of launching the first American satellite which was about the size of a grapefruit, the number and complexity and capability of satellites has grown steadily.

The Navy has had an operational navigation satellite system since 1964 orbiting the globe and sending position-fixing signals back every two minutes. This navigation satellite system is now available for commercial use. Navigation satellites are particularly useful to oceanographers in exploring and charting the ocean floor. It is now possible to pinpoint the location of undersea oil deposits with increased accuracy.

[17, 18] Helms, <u>op. cit.</u>

Weather satellites provide constant and daily information to the U.S. Weather Bureau. Tiros III provided advance information on Hurricane Carla, which resulted in the greatest mass evacuation ever to take place in the United States. Over 350,000 people were moved from the path of the storm. There is no way to determine how many lives were saved. The continual improvement in techniques of interpretating data from this type of satellite and the improvements in the satellite itself offers the possibility of accurate forecasting of weather over vast regions. An accurate five-day forecast of weather conditions over the United States alone would provide an estimated annual savings of 6.75 billion dollars when applied to agriculture, lumber business, surface transportation, retail marketing, and water resources management. The $6.75 billion annual saving is more than any single years cost of the total national space program.

We recently started to cooperate with other nations of the world to improve the world-wide weather forecasting system in an effort originated here in the United States from our national space program.

Weather ships used in the North Pacific cover only an area represented by a 60-mile diameter circle and the ships cost a million dollars a year to maintain and operate. This amounts to $350 per square mile per year. Each photo from the weather satellite covers 630,000 square miles at a total cost over a year's period of only 25¢ per square mile per photo.

Weather satellites survey the ice fields of the Gulf of St. Lawrence with an estimated savings to the United States and Canada of 1.7 million dollars each year by more accurately predicting the opening of shipping on the Great Lakes.

Great swarms of insects cover wide areas in Asia and Africa and have been accurately tracked as to speed and direction by weather satellites, giving a forewarning of the threat to crops.

After man fully understands the weather with the help of satellites, he may actually be able to control it. Even a limited control of rainfall, storms, and trade winds would bring untold benefits to mankind. The ability to predict floods, ice movements, beach erosion, water pollution, fish migration, and assist in fresh water level management, crop surveys, making better maps, measuring soil moisture, checking inadequate soil fertilization, evaluating

certain crop diseases, etc., merely scratch the surface of possible new benefits from space satellites in addition to those we get today.

A more personal example of how space technology affects our daily lives is the introduction a few years ago of a new high-speed dentist drill. This ultrafast drill is much more effective, significantly reduces the pain, and practically eliminates any sense of vibration or grinding. The basis for this high-speed dental drill was the development of pin-point-size ball bearings which could stand the high rotational speeds for extensive periods of time and yet hold the drill itself in a firm position. These ball bearings were initially developed to fulfill the satellite requirements.

In the steel industry, a large portion of the annual output is thin sheet metal produced in continuous rolling mills. In these mills a single continual high speed process starts with molten metal sized and shaped through large rollers to a given thickness and strip width, then passes on to large spindles much like paper tape on an adding machine. The output of steel in such a mill is at a speed of 30 to 50 miles per hour. It is very expensive to stop this process once it has been initiated. While every effort was taken to ensure the proper thickness of the strip as it rolled through the mill, the response loop from the time of sensing an accuracy measurement to control of the dimensions by rollers themselves allowed large variations. This could result in a strip being of too thin gauge and a sudden catastrophic rupture of the metal strip. Hundreds and occasionally even thousands of feet of metal would be wasted and jammed into the receiving area before the mill could be shut down. Additionally, many man-hours and dollars were lost in reestablishing the process, increasing the cost of the steel and the products in which it is used.

Today, continual measurement of the uniformity of thickness of steel plate in rolling mills without them being stopped or cooled or hand measured is available by use of an infrared sensor. This sensor accurately measures the amount of heat energy at a given time which is directly relatable to the thickness of the metal at that point in time. That infrared sensor was originally developed as a horizon sensor for the Nimbus satellite, a technique for keeping a satellite continually pointing at the earth.

The last ten years have seen a phenomenal increase in the movement of automobiles over vast freeways. One of the first areas to undertake large scale freeway development was Los Angeles. Freeways are intended to handle a high volume continual stream of traffic and any unplanned emergency immediately starts to choke the system. The Los Angeles freeway complex includes emergency radios to provide a "call system" in an emergency.

In a small section of South Africa there was a need for a telephone system in an area devoid of normal energy sources. Both the Los Angeles freeway system and the telephone system in South Africa use solar cells as their energy source. The solar cell, a device which converts sunshine energy into electrical energy was developed to fulfill the need of satellites for a continual power supply. All you need is periodic sunshine. These high energy solar cells came from our national space program.

In the spring of 1961 U.S. News and World Report conducted an interview with James E. Webb, NASA Administrator on the subject of, "Why spend $20 billion to go to the Moon?" One of the many questions and Mr. Webb's answer are repeated herein as being particularly pertinent and prophetic.

> Q. Suppose the U.S. used half of your budget for eliminating slums and rebuilding cities -- wouldn't that mean more in terms of the fullness of life and economic well-being of our people than developing space?
>
> A. This is a very hard question to answer. But, on the other hand, I would like to just say this: If you fall behind in this technological race, and, let us say, the Russians find out how to operate in space with men, and we don't, you cannot be sure that this may not really eliminate the possibility of eliminating the slums.
>
> You simply cannot afford to fall behind in a major forward area of technology without running the risk of paying a severe penalty. And if you can do it -- if you have the resources to do it -- then, it seems to me, the only sensible form of national insurance is to go forward and do it. But, more specifically, much of the technology we are developing will be of great value in solving the problems you mention.

> Dr. Lloyd Berkner, chairman of the Space Science Board of the National Academy of Sciences, has made two points: that communication satellites may prove capable of multiplying our long-distance-communication resources by a factor of 10,000; and that whole new ways of conducting scientific sampling and analysis in space, in fractions of the time now required on earth, will be perfected.
>
> Both of these would have great value in improving our cities and adding to the fullness of life. What we do in space will have great theoretical and practical value here on earth.[19]

Sen. William Proxmire, a Democrat from Wisconsin, speaking for those who oppose the space program, took to the Senate floor this spring during the debate on the NASA appropriations bill to plead with his colleagues to support his amendment to slice $122 million from the space program. The money, he said, is more than that provided for the school milk program, and enough to provide 125,000 new homes for poor people.

Sen. Alan Bible, a Democrat from Nevada, a state which receives less than half of one percent of NASA's contract dollars, then defended the space program. Excerpts of his speech follow. The Proxmire amendment was defeated 38 to 35.

> We are making decisions today, Mr. President, that transcend appropriation considerations and spending priorities. These decisions go far beyond the National Aeronautics and Space Administration budget. They go to the heart of our Nation's vitality today and its course in the future. We are deciding whether the United States shall continue to exert leadership in science, technology, and industry and blaze new trails into mankind's future, or whether we shall retrench and abandon the demands of the future in favor of concentrating on the domestic problems of today.
>
> Perhaps that sounds like an unfair generalization. I think it is not. We can take all the arguments that have been advanced for reducing NASA's budget and boil them down to one basic contention--that we should put off our sophisticated space exploration and divert the money instead to the Nation's

---

[19] "Why spend $20 Billion to go to the Moon", U.S. News and World Report, An interview with the NASA Administrator, James E. Webb, July 3, 1961.

serious domestic needs. It is a declaration, essentially, that we have too many problems, too many needs, right here at home to afford any serious and effective activity in space. It is an argument that is powerfully persuasive--and politically attractive in these troubled times. But it is a policy that could turn this great Nation from the road to future greatness and send it down a dead end street of muddled mediocrity.

We must do everything we can to deal with today's problems of housing and poverty and education and opportunity. In the process, however, we must avoid the temptation of ignoring the equally pressing needs of the future.

Mankind would still be stumbling around in the dark ages if it had tried to solve all of its domestic problems before exploring the challenges of the unknown. There were problems at home when Columbus set sail for the new world. The money that was spent to build a railroad across the continent--surely it could have been better used to improve education and working conditions here in the East. The Wright brothers would have had less ridicule and criticism if they had concentrated their inventive genius helping the poor. I could go on indefinitely.

The point is that every important advance in the history of mankind would never have occurred if it had been put off until other, more immediate needs were handled. But each of these advances brought benefits to mankind that far outweighed the alternatives that might have been offered. Who could have forecast early in this century, for example, that the Wright brothers' tinkering with a kite and an engine would lead to the mammoth transportation industry--and all the benefits that industry provides--in little more than 50 years? We can only begin to surmise some of the benefits that await our continuing exploration of space. Undreamed of advances lie beyond if we have the courage to support the fine beginning we have made...[20]

[20]Space Daily, Washington, D.C., Shall We Abandon the Demands of the Future, May 1970, p. 49.

Medical Benefits

Probably the field of the space program which will provide the greatest personal benefit to the American citizen is the area of medical equipment and its application to improving our national health.

Before proceeding with benefits which are in actual use now, let me describe a project which within the next 10 to 20 years may enable the blind to "see" again.

At the Albert Einstein College of Medicine in New York City, Dr. Herbert G. Vaughan, Assistant Professor of Neurology, has a research grant from the National Institute of Neurological Diseases and Blindness, Bethesda, Maryland and has been conducting experiments on the feasibility of providing electronic signals directly to the visual nervous system utilizing a television camera to replace the eye.

The possibility of restoring sight by this method has been commented on many times in the technical and public media. In a recent report by the committee on Science and Astronautics of the U.S. House of Representatives, a comment was made on this possibility.

> Also in the future is a small TV camera devised by space research which, worn on the forehead, will scan a blind person's surroundings. There, bypassing the sightless eyes, it would transmit an image to a tiny teflon-insulated receiver in the visual cortex of the brain, enabling the blind to "see". The camera might eventually be miniaturized to fit into an eye socket. It may take a decade or longer to perfect this marvel, but the technology is on its way.[21]

In a recent article the Seattle Times[22] reported on a statement by Professor R. W. Mann of the mechanical engineering department at the Massachusetts Institute of Technology. Professor Mann stated that artificial sight for the blind is an almost certain development of the future. He said that patterns of light that form optical signals would be picked up by electronic sensors instead of by the eye.

---

[21] Report of the Committee on Science and Astronautics, loc. cit., p. 20.

[22] The Seattle Times, Artificial Sight Called Possible in Future, Monday, May 18, 1970, p. A19.

The most promising electronic sensor in this case would be a tiny television camera about the size of a pack of cigarettes and then an advanced version about the size of an ice cube with future possibilities to reduce it to the size of a small sugar cube. Both versions were developed by commercial electronics companies under NASA contract.

In an article in the Mount Vernon Daily Argus[23] on the same subject, Physicist Herbert Schimmel, a colleague of Dr. Vaughan on the Albert Einstein College project, said tests with animals should come in 1971-72 followed by tests with humans in 1973-74.

This tiny television camera has other application and could, for example, be lowered into a patient's stomach for a detailed study of ulcers. In the blindness project the possibility exists to mount the camera into artificial eyeballs.

Other promising medical innovations and advances made possible by space research related projects are:

A robot-like lunar walker, designed to aid astronauts and their equipment in traversing the irregular surface of the moon, is being experimentally adapted for use by paralytic children. They can maneuver it over curbs and steps, and thereby "walk" for the first time.

In the past a severely paralyzed person could look forward to a dismal future of virtual immobility. Today, thanks to the "magic glasses" developed by space technology, a paralysis victim can steer a motorized wheelchair with a "sight switch" -- triggered by movements of the eyeball!

The cleanliness requirements during the assembly of space hardware have created developments in contamination controls which are now finding their way into hospitals. These developments, which are in operation in the space industry, include laminar flow facilities. Laminar flow means that the incoming air which has been cleaned by filtering flows smoothly without turbulence. These laminar flow facilities are presently being used for severely burned patients.

---

[23] The Daily Argus, Mount Vernon, N.Y., TV May Give Sight to Blind - Camera May Fit in Eye Socket, Ralph Dighton, AP Science Writer, November 10, 1969.

Along with laminar flow a new air filter called HEPA (high efficiency particulate air filters) and Super-HEPA filters are being used in the space industry. These filters can physically remove all bacteria. Thus with these filters and laminar flow, operating rooms and recovery rooms can be free of bacteria-type diseases from other parts of the hospital.

Another medical advancement is the discovery that some high purity, high strength carbon forms which were developed for the Aerospace activities are chemically, biologically and physically compatible with fluids and tissues within the human body. These forms of carbon can be fabricated easily into variable shapes and easily sterilized. Because of these characteristics, these materials may be the next order of materials used in surgical implantations in splints, bone extensions, circulatory bypasses, replaceable heart valves and other implantable protheses.

Other examples of medical spinoff benefits of the space program are grooved highways which are reducing rainy day auto accidents by as much as 90 percent where used, developed as a result of NASA studies of aircraft skidding on wet runways. A sensor for wind tunnel research, smaller than the head of a pin, can be inserted by means of a hypodermic needle into a vein or artery to measure blood pressure without interfering with a patient's circulation. A West Coast hospital has used the sensor to evaluate implantation of artificial heart valves and the National Heart Institute is monitoring progress toward commercial development of these cardiac catheters.

A transducer developed for the Manned Spacecraft Center to measure the impact of the Apollo Spacecraft Command Module during water landings is being used in the fitting of artificial limbs. The transducer is smaller than a dime and weighs less than an ounce. The sensing diaphragm is stainless steel and the whole unit is waterproof. As used in the Command Module, or in the hospital, it will respond to static or dynamic changes in pressure, and is not affected by temperatures between freezing and 120°F.

Another medical transfer example is a breathing sensor which has been modified from integrated circuitry designed and fabricated for aerospace use by NASA's Ames Research Center. The modification

enabled the detection of differences in air temperature passing through a tube causing actuation of an audible or visible alarm within 10 seconds of any change. The device can be used on infants, comatose children or adult patients who require surgical implantation of a tracheotomy tube in the windpipe to ease breathing. If the tracheotomy tube is clogged, cutting off breathing, brain damage or death can result within from two to four minutes. Ordinarily a full-time nurse is required, who checks the tube visually and takes immediate corrective action when necessary. With this transducer sensing device, the signal can be given to a nurse's station or in another room if the patient is at home. Thus the patient's care is improved and facilitated.

An EKG (electrocardiogram) transmitting system whose technology was developed at NASA's Edwards Flight Research Center for monitoring astronauts during actual and simulated space flight now enables a physician to obtain EKG data on a patient before he sees him. An EKG taken in the ambulance transferring the patient to the hospital is transmitted by radiotelemetry direct to the physician who will handle the case. Interest by physicians and a local ambulance firm in improved patient care made the development possible.

Another heart monitor space research transfer example was developed by an investigator working under a NASA grant at the Duke University Medical Center who wanted to monitor heart action more precisely by measuring electrical signals simultaneously along 15 points on a small area of the heart wall. For this he needed a probe that would insure good contact at all 15 points and which would not result in heart wall damage upon insertion. The NASA-sponsored Biomedical Applications Team at the Research Triangle Institute in Durham, North Carolina explained the problem to an instrument engineer. He designed a 15 electrode probe within an ordinary hypodermic needle. It was fabricated, tested, found satisfactory and is now in use.

Cancer is a dread human disease principally because its cause is for the most part unknown and strikes down many thousands of people prematurely and in many cases in a particularly painful and prolonged manner. Recently Mr. Clarence D. Cone, Jr., a NASA scientist and head of the Molecular Biophysics Laboratory of the NASA Langley Research Center in Virginia was studying radiation effects on cells in order to understand possible space radiation effects on astronauts.

Cone discovered that the electrical voltage across the surface membrane of a normal cell acts to exert precise control over cell division. This implies that it is an alteration in the molecular structure of the cell surface that permits the uncontrolled proliferation of malignancy and metastasis characterizing cancer. Metastasis is the transfer of disease from one part of the body to another not directly connected with it. In other words, a lower electrical voltage permits unrestrained cell growth. This new theory which has been verified in preliminary tests has opened a promising new avenue for possible chemical (and/or electrical) control of cancer. Mr. Cone has written a paper on the subject titled; "Control of Cell Division by the Electrical Voltage of the Surface Membrane".

Another example from NASA's biological research in support of the space effort highlights the interaction of science and technology and how work in one area will lead to advances in other areas. In other words a "spinoff" is realized. Dr. Fernandez-Moran at the University of Chicago was working on cell structure for NASA, but his research needs required a microscope beyond the range of commercially available electron microscopes.

Dr. Fernandez-Moran's resulting improvements produced the worlds most powerful instrument of this class capable of magnifying objects 20 million times and resolving images down to two angstroms, an angstrom being one hundred-millionth of a centimeter and is used in expressing the length of light waves.

In order to use the required operating electric power without melting the microscope another breakthrough was achieved in cooling the magnetic lens by developing the first large scale continuous closed-cycle production of superfluid helium.

Breakthrough after breakthrough followed. In order to use the full magnifying power of the microscope, it was necessary to prepare specimens to the same scale. The diamond knife invented by Dr. Fernandez-Moran to solve this problem can dissect away portions of a molecule or cut a hair into 10,000 length-wise strips. In order to record images from the electron microscope, a virtually grain-free film was required and invented. The film can even be converted into color images by interference microscopy. These developments resulting from this one scientific investigation in space research illustrates the many benefits in various fields which work in space science is stimulating.

In a booklet prepared by Baylor College of Medicine titled; "Preservation of the Human Heart"[24] the introduction partially states:

> One of the goals in cardiac transplantation research is the ability to preserve the heart in a viable state outside of the body....The Cardiac Preservation Chamber used in this research program was designed and constructed by the same aerospace corporation [Grumman] responsible for the development of the lunar module (LM) which landed the first American on the moon. Several technological features of the chamber were derived directly from experience gained in solving the environmental control problems of space.
>
> Future advances in cardiac transplantation will depend upon future research in basic immunology tissue typing, and organ preservation. Additional "spin-off" benefits from the aerospace program are expected to contribute to both the heart transplantation program and fundamental studies of cardiac metabolism and function.

U.S. Congressional Representative John W. Wydler of New York at a speech before the committee on Science and Astronautics in 1970 on the subject of space program benefits commented on the Cardiac Preservation Chamber developed by Grumman.

> Let me cite one example of [space program benefits] which I am personally aware, because it is an outstanding accomplishment of the Grumman Aircraft Corp. Most of the Members probably know that Grumman has been deeply associated with the Apollo program as the manufacturer of the lunar excursion module or the LEM. During the course of research into biomedical aspects of the LEM, Grumman engineers became aware of work being done by Dr. DeBakey, the famous specialist in heart transplants, in developing a device by which hearts and lungs could be kept alive and transported from one place to another. This was needed because donors and recipients sometimes cannot be brought together in the same hospital.
>
> The Grumman engineers quickly saw that by applying Apollo technology to this development, they could produce an efficient and highly reliable device to do the job. This device is already being used to great advantage by giving to

[24] Report by Baylor College of Medicine and the Cardiovascular Research and Training Center of the Methodist Hospital, Houston, Texas, Preservation of the Human Heart, Edward B. Diethrich, M.D., John E. Liddicoat, M.D., Arnold Schwartz, Ph.D., Louis A. Sordahl, Ph.D., David K. Brooks, M.D., Michael E. DeBakey, M.D., p. 1.

medical researchers at the Baylor College of Medicine a means by which they attack the problem of organ incompatibility and rejection. This we all know, is the principal obstacle to be overcome in providing longevity to people with new hearts. It will also be a great step-up in tracking body rejection of other organs such as kidneys.

The spray-on electrode is an interesting development. Normally when one has an electro-cardiogram, the technician applies a metal electrode to the chest and moves it about. In addition, he connects wires to the wrists and ankles. These electrodes are satisfactory for short contacts but in doing dynamic monitoring of the heart they have proven to be inadequate. Under NASA sponsorship, a spray-on electrode was developed. One merely sprays this electrode over the end of a lead wire which has been greatly miniaturized and these are connected to the electrocardiogram machine. This flexible layer of material will secure the electrode, even though the patient is moving about.

The use of computers to enhance X-rays is proving to be of use in getting a clearer picture of deep inaccessible portions of the body hidden behind boney areas which are often distorted or unclear on the X-ray film. The technique was first used to clarify the photos of Mars transmitted by the unmanned Mariner spacecraft. The computer converts the X-ray picture into digital forms and then converts each point of the picture into a number proportionate to the films optical density with a resulting reproduction of high clarity. These enhanced pictures are being used in studies of the heart and great blood vessels as well as vessels in the brain.

The Integrated Medical Behavioral Laboratory System is being developed to fly in a spacecraft in the mid or late 1970's. This is a modularized flexible system which would have the capability at one sitting of measuring a good many physiological and psychological factors and integrating them into a picture of the individuals total condition. This laboratory should prove a great boon to hospitals and physicians offices by simplifying and speeding up the process of biochemical, behavioral and physiologic measurements. It may well be considered one of the greatest breakthroughs in diagnostic instrumentation in many decades.

Many statements have been made recently in speeches and in newspaper articles about the importance of the environment. It is a great coincidence that this sudden urgent awareness of our fragile deteriorating ecology has come to our attention in frightening perspective at the same time as and because of photos of earth taken from spacecraft flying a considerable distance away from earth. A recent short article in a recent church bulletin[25] discussed this aspect in a convincing manner.

> When the first photograph of the earth taken from outer space flashed on our television screens, the almost universal reaction was one of surprise and shock. Our familiar earth, appearing little larger than the moon seems to us, hung framed against the dark background of an endless void. In the silent immensity of space, the earth seemed so tiny, so fragile, so alone! On every side it was enveloped by an impersonal, inhuman cold and darkness.
>
> The final telecast from Apollo 8 brought home another side of the picture. "See you back on the good earth soon," said Frank Borman. Suddenly we realized that the earth, small though it be, is man's home.
> ....
>
> The problem of conserving the earth as the dwelling place of man has been summarized by the head of the U.S. Department of the Interior:
>
> "We have carlessly assumed that nature can absorb unlimited punishment. Now we are paying the bill.
>
> Our national production machinery is humming, but at what price? Oil from offshore pollutes beautiful beaches and endangers marine life: air pollution injures health; pollution from human and industrial waste threatens our streams; poisonous pesticides and fertilizers contaminate our food; one of the great lakes is fatally ill.
>
> We must attack the noise, the smoke and fumes, the dirty water, the crowding, the ugliness, the tension and stress."

---

[25] Bulletin of St. Cyril and Methodius Church, Deer Park, New York, Conserving God's Good Earth, October 11, 1970, p. 1 and 4.

Representative Fulton of Pennsylvania had an interesting comment on this aspect.[26]

> The success of our effort to reach the moon provided a new view of earth. We were able to see it as a whole; and this new view provided us with a deeper appreciation of its bounty. I am certain that this view has contributed to our recent intensified concern for our environment and the growing resolve to decrease pollution by managing the life-support systems of "spacecraft earth" as carefully as we do those of the Apollo spacecrafts. Space has given us a greater awareness of our mismanagement of earth and an increased regard for our future and our destiny.

In January of 1970 a Lunar Science Conference was held at Houston to present the results of experiments with material collected by Apollo 11. At that conference, Mr. Fred Hoyle, famed for his theories on the origin of the universe, suggests that humanity may, in the final analysis, owe its very survival to development of the space program.

Hoyle recalled a 1948 prediction he made that once the Earth was photographed from outer space the sheer isolation of the planet would become evident and new ideas as powerful as any in history would be let loose. He feels his prediction has been borne out.

> [27]Suddenly everyone has become seriously concerned to protect an excellent environment although biologists have been saying the same thing for years and never got on base.
>
> Something new has happened to create a worldwide awareness of our planet as a unique and precious place and it seems more than a coincidence that this awareness should have happened at exactly the moment man took his first step into space.

---

[26] Speech by Representative James G. Fulton to Canadian Club in Hamilton, Ontario on March 18, 1970.

[27] MSC News, Houston, Texas, Space Program Worth Cited - Direct Link With Human Survival, Vol. 8, No. 1, p. 1, January issue.

The lunar soil that has been brought back has some interesting possibilities. Representative Louis Frey, Jr. of Florida said[28]

> Within the last month [March 1970] a sample of moon soil killed three common earth bacteria and Dr. Gordon Zubrod, Chief of the National Cancer Institute's drug investigation program, has asked for a sample to test its anticancer potential. True, no one knows if this moon dust will actually be useful. In fact, no one ever thought it had the potential to kill bacteria. Yet is this not true of most new discoveries?

On the same subject of the lunar soil, Representative James G. Fulton said[29]

> An exciting result of our manned flights to the moon has been developed out of the moon soil that was brought back by Astronaut Neil Armstrong and his crew of Apollo 11. One of the experiments conducted by the Houston Manned Space Flight Center was to determine whether or not moon soil could support plant growth. The experimenters selected a moss like plant called liverwort, and planted some in earth soil and some in lunar soil. Much to their surprise, without using any fertilizer in either sample, the plants in the lunar soil grew significantly faster and reached greater size than the plant [sic] in earth soil. To me this has great significance. If we are able to determine what caused the lunar plants to grow faster and larger than the other, think what this will mean to the food problems plaguing the approximately two billion people of the have-not nations across the world. Think what this would mean in terms of manpower that could be released from agriculture to the underdeveloped nations out to an expanding industrial base necessary for economic development.

Astronaut William Anders who flew in Apollo 8 which orbited the moon in an article in Boy's Life Magazine[30] on the effects of the space program had this to say about the lunar soil properties.

> I recognize that there have been some complaints about the high cost of the U.S. space program. We spend four to six billion dollars a year on space - and, while that's a lot of money by anyone's standards, it is actually no more than we spend each year on

[28] Speech by Representative Louis Frey, Jr. to the Science and Astronautics Committee (April 21, 1970.

[29] Fulton, op. cit.

[30] William Anders, The Moon, The Earth, and the Future, Boy's Life Magazine, May 1970, p. 39, 40.

breakable toys or such throwaway sports supplies as tennis and golf balls. I believe we have been getting more than our money's worth and that the program [space] is a tremendous bargain. It is literally the spearhead of our modern technology development.

Take agriculture for example
....
There is so very much that can be learned. Take the dust Neil Armstrong and Buzz Aldrin brought back from the moon. Does it have a detrimental effect on plants?

To find out, researchers at the Manned Spacecraft Center conducted some fascinating experiments. They put this moon dust into a solution and then added a little of the solution to various plants. We found that some plants grew twice as fast as they normally would. Is there something in lunar dust that accelerates growth? If so, and if we can find out what it is, then we could add the mystery substance to common fertilizers. A slight improvement in the world's rate of food production could pay for the entire Apollo program in one year.

The lunar soil also yielded other surprises, a Newsday article[31] commenting on preliminary findings reported that gold, silver and a ruby had been discovered in the moon samples collected by the crew of Apollo 11, the first manned lunar landing. The gold and silver were reported by Edward Anders heading a six man University of Chicago team. He said that the precious metals were present only in tiny amounts - "too small to finance the space program", he joked. Anders said he believes that 98 percent of all gold on the moon was deposited there by meteorites.

Robert M. Walker of Washington University in St. Louis said that he had found a ruby in his moon sample, but that it was so small that he had to use a microscope to detect it.

[31] Newsday, Long Island Newspaper, Paydirt in Moon Soil, Tuesday, January 6, 1970, p. 9.

With increasing yield the by-product benefit of the massive U.S. space research and development effort are appearing in every day use. Several thousand technological innovations have been directly attributed to the space program, including new alloys, miniaturized electronic components, non-flammable cloth, biomedical equipment of many types, new food treatment methods, inorganic paints, new flexible pipe for fluid conveyance, greatly improved batteries, microminiature parts, new processes, techniques and systems that are directly translatable to the profit of America's general industry and ultimately to the world.

In addition to the products which come directly from space technology, we have no way of knowing how many others have been indirectly inspired by the stimulus to engineering which derives from the necessity to create new solutions to new problems, and we need an endless line of new solutions--new products. Some time ago, RCA reported that 80 percent of their current sales was of products which were not invented 10 years ago.

Weather satellites, government owned, are a major advance in our ability to deal with our environment. Geologists are finding that space observation offers them a valuable business tool. A Gemini project photograph of the western desert of Egypt was examined by an Egyptian geologist working at the University of California. He saw photographic evidence that mineral deposits in this area were at least 4 times as large as earth research has shown.

An earth fault, similar to those in the oil-rich Arabian peninsula, showed up in space photos in northeast Africa where oil has not yet been found. Oil companies are using satellite photographs to locate potential oil bearing areas on the ocean floor. It is possible that oil companies will finance their own space satellites as a more economical means of finding deposits as compared with conventional exploration techniques.

James J. Haggerty recently wrote an interesting and comprehensive article for the Air Force and Space Digest on the benefits of the Space Program[32]. Mr. Haggerty is a leading aerospace writer, he has served on the staff of Colliers Magazine and Look Magazine. He

---

[32]James J. Haggerty, The Giant Harvest From Space - Today and Tomorrow, Air Force and Space Digest, February 1970, pp. 30-43.

was also a reporter for American Aviation Magazine, Aviation Daily and the Journal of the Armed Forces. He has written extensively for encyclopedias and is the author or co-author of eleven books in the field of aerospace and is the editor of the Aerospace Year Book. He has won a number of awards for his aerospace reporting.

Mr. Haggerty feels that the U.S. space investment is already paying handsome dividends, "hard" benefits of practical value as well as little understood gains in scientific knowledge and national prestige. The benefits include new techniques, new processes, new services, new products, even new companies formed to exploit the wealth of technological know how accumulated in twelve years of concentrated space effort. Collectively, says Haggerty, these innovations contribute to an improved standard of living and produce a concrete boost to the general economy running to tens of millions of dollars. He feels that the benefits now being reaped are only a trickle compared with the flood to come and not in the future but now, within the decade just starting. He feels that the real payoff is about to begin and just the evident benefits are tremendous in potential. Although what he says has essentially been stated elsewhere in this thesis, I would like to quote directly a general statement by Mr. Haggerty on space program benefits:

> They [space program benefits] span a broad spectrum ranging from new levels of convenience to direct applications in the most pressing areas of global concern - food shortages in an overpopulated world, public health, air and water pollution, education, transportation safety, law enforcement, and urban development. They [space program benefits] promise new levels of business efficiency, improved resources management, accelerated discovery of oil and minerals, and reduction of life and property losses from natural disasters.

Haggerty describes space benefits as being in one of two categories. "Derived" benefits are those, like new products and processes, derived from the general fund of technological knowledge. "Direct" benefits are those provided by orbiting spacecraft or "applications" satellites, which do earth jobs better or perform tasks that cannot be accomplished by earth-based systems.

Congressman George P. Miller of California, Chairman of the Committee on Science and Astronautics House of Representatives, on August 6, 1970 compared our present space exploration with the era of Earth exploration some 400 to 500 years ago. He said that after Columbus showed the way in 1492, there were almost 100 voyages to the new world in the next decade; and the nations that led the world politically and economically for centuries were those that led in continental exploration - particularly England, France, Italy and Spain.

Congressman Miller also mentioned how Mark Twain once remarked that everybody talks about the weather but nobody does anthing about it. Congressman Miller said no longer is that true. He said we now have vastly improved weather forecasting, and we have a potential of weather control or modification, largely by means of new tools developed by NASA in the space program. These tools include sounding rockets, satellites, radar and lasers, computer systems and highly efficient data transmission systems. Since 1966, U.S. weather satellites have watched every major storm threatening the nation.

Soon to come into being are the Earth Resources Satellites which will bring unprecedented benefits. These unmanned space vehicles will be able to pinpoint early indications of crop disease, previously undiscovered sources of fresh water, the beginnings of locust swarms in barren country and global weather patters.

Representative Charles A. Mosher, Ohio, a member of the Committee on Science and Astronautics, in a speech before that committee in April of 1970, discussed our weather satellites and the NASA Applications Technology Satellites (ATS) equipped with Automatic Picture Taking (APT) systems. These satellite systems have made weather information available to all nations. More than 50 countries today are able to view daily weather patterns over their own territory. And through the World Meteorological Center every nation has access to cloud picture mosaics from our satellites. The mosaics are routinely made available to the Center by our Weather Bureau.

Captain James Lovell (astronaut) commented[33] on this weather satellite system when he stated:

> Space technology offers tremendous opportunities for international cooperation on a basis of mutual benefit rather than as a means for mutual defense. For example, any nation in the world can make use of the data and cloud cover photographs supplied by our weather satellites simply by installing an Automatic Picture Taking Transmission Station.

To give one example of the quantity of weather information available and the information gathering capability of the weather satellite, NASA's Nimbus III, launched last April, carries a new infrared spectrometer to measure the vertical temperature of the atmosphere. It has proven highly accurate and has transmitted daily from orbit the equivalent of 10,000 conventional atmospheric soundings by balloons or sounding rockets. Its use operationally for weather forecasting began last June and has significantly improved prediction with respect to upper atmosphere flow.

Representative Louis Frey, Jr. of Florida, member of the Committee on Science and Astronautics made some extensive comments before the committee on April 21, 1970 on the benefits of the space program to our weather forecasting ability. Some of the highlights of that speech are mentioned in the paragraphs that follow.

> Beginning in the early 1960's the space program developed and put into operation revolutionary new systems for weather forecasting. In 1969, Hurricane Camille killed 256 persons, another 68 are missing and presumed dead and the total damage is estimated at $1.42 billion, yet this deadly hurricane's path, force, and extent were predicted early and accurately enough by a satellite to permit the evacuation of 70,000 people from the affected gulf coast states. Without this warning ESSA estimated that 50,000 people might have lost their lives.

Before satellites, such as the ESSA satellite which observed Camille, a storm could be born unobserved in the tropical seas and sweep into an inhabited coastal zone without warning, driving a wall of water before it and wind ripping towns into kindling. One such

---

[33] Speech by Captain James Lovell, U.S. Navy, NASA Astronaut, at Rockhurst College, Kansas City, Mo. describing benefits of the space program, May 14, 1970.

storm at the turn of the century claimed 5,000 lives, most of them in Galveston, Texas; another killed 4,000 in the West Indies in 1928, and as recently as 1959, 1,500 lives were lost to a killer-storm that struck Mexico.

The advent of the weather satellite system has brought a sharp reduction in storm casualties. From its sentry post in space, the satellite can detect the buildup of a destructive storm and alert meteorologists to its existence. Weather satellites now do more than just photograph the clouds. With the new sensors, satellites take pictures not only in the visible light spectrum, but also in infrared, showing cloud patterns by night as well as by day. A continual relay of photos enables the weatherman to track the storm, estimate its force and predict with accuracy when and where it will strike inhabited areas.

Continuing with Congressman Frey's speech, he said:

> A severe freeze in Florida 2 years ago /1968/ damaged citrus and other agricultural crops to the tune of $100 million. In California last year major floods caused $265 million in damage. In a 1966 speech Dr. Glenn Seaborg, presently Chairman of the Atomic Energy Commission, estimated that if weather could be accurately predicted even 3 days in advance, man could save $60 billion a year. Yes this is billion, not million. His estimates came from a comprehensive 17-volume study made by the IBM Corp. on the ability of satellites to improve weather forecasting. While the study assumes that the forecast would be 90 to 95 percent accurate and that the respective agencies or corporations involved would act immediately to minimize the effects of severe weather, this is an amazing prediction. A study panel of the National Academy of Sciences' National Research Council rated economic benefits of a long-range forecasting system at $2.5 billion yearly. This estimate covers only the four broadest and most visible areas of benefit - agriculture, construction, transportation, and flood-storm control - and is for the United States alone.
>
> ....
>
> The Nimbus III satellite launched in April of 1969 for the first time relayed to earth a vertical profile of atmospheric temperature from the ground to the upper level of the atmosphere. This has advanced our present meteorological satellites immensely - as presently they are based on cloud

> cover photos. This is not enough, as the primary clues to the distribution of solar energy - and hence the type of weather - are temperature, pressure, the movement of air masses, and the moisture content of the air. Today the information is obtained from 700 stations covering only one-fifth of the earth's surface, and these reports are periodic rather than continuous. The only way to obtain the required data on the entire earth is by satellites. The only way to collect, analyze and disseminate the information is by an integrated, computerized data transmission facility. The required new sensors will be tested through Nimbus and application technology satellites. ESSA hopes to have operational satellites by 1972. If all goes well, and this includes adequate funding, the system will be in full operation by the end of the 1970's, giving us the weather not 3 days, but 2 weeks in advance.

Representative D. E. Lukens, Ohio[34] gave a recent interesting example of the use of weather satellites:

> Late in 1968, very heavy rains filled the Nazas River Valley Dam in Mexico to a dangerous level which threatened to break the earthen dam. In order to relieve the pressure, it would have been necessary to release great quantities of water that would have wiped out the towns of Torreon and Gomes Palacios. But the Mexican authorities had available to them weather satellite readouts that showed the weather was clearing to the west. As a result the dam was not opened, the weather did clear, and the previous irrigation supply and the towns were preserved. What value do you think the Mexican officials place on the information they received from space?

Continuing his talk he spoke about the new forthcoming family of satellites called earth resources satellites, he said:

> We will gather in great detail knowledge of sources of continental water supply important to ever expanding human population. For example, in this instance, we already discovered from space very large seepage of fresh water draining out of the Continental Shelf under the surface of the sea in such places as off the coast of California and the Red Sea.

---

[34] Speech by Representative D. E. Lukens, Ohio, Member, Committee on Science and Astronautics, Spring 1970 on the subject of Space Program Benefits.

The prospect of accurate global weather forecasting is imminent with the advent of mankind's capability to orbit satellites. Last September (1969) Nimbus III, NASA's most advanced meteorological satellite, relayed to earth a complete profile of the temperatures at every altitude from the ground up to the top of the atmosphere. This was compared with a concurrent reading from an instrumented balloon and found to be almost identical. This was a momentous achievement and constituted a scientific breakthrough in meteorological satellite development. The instrument used was a Satellite Infrared Spectrometer (SIRS) which made possible a vertical sounding temperature reading. This sensor coupled with other metsat advances and improvements in the ground-based weather-analysis system hold the key to accurate weather forecasting two weeks or more in advance. A little thought on the matter would seem to indicate that long-range weather forecasting is potentially one of the most productive areas for harvesting benefits from space technology.

At present the satellites most important utility has been the detection of destructive storms and its subsequent tracking and estimation of force and impact. The present limitation is that the orbiting satellite only looks at the area once every two hours. A synchronous satellite is needed for continuous coverage. At present only cloud cover is observed. Other information is concurrently needed such as temperature, pressure, air mass movement and the moisture content of the air. This additional information is currently obtained from aircraft, ships, rockets, balloons, ocean buoys, radars, and ground observations. The 700 stations periodically reporting the data cover only 1/5th of the earth's surface so it can be seen that we are a long way from global long-range weather forecasting by present methods.

What is needed obviously is a synchronous metsat system equipped with all the necessary sensors. The information gathered must then be analyzed, translated into usable form, and delivered to weathermen all over the globe. A vast interconnected computerized data-transmission system thus becomes a must. A mathematical model of the atmosphere is also a requirement. This provides a computerized numerical representation of the composition of the atmosphere in order

to determine what the weather will be like under a given set of reported or anticipated conditions.

In order to realize the goal of the mathematical model and the data-relay system more than 100 members of the World Meteorological Organization are engaged in two massive projects called the World Weather Watch and the Global Atmospheric Research Program (GARP). The Weather Watch is a surveillance system for establishing a worldwide, computerized telecommunications network for transmitting and processing meteorological data. GARP is a research program to help understand the atmospheric processes well enough to develop the math model.

Over the next few years, NASA will space-test the various sensors based on photographic, infrared, microwave, radar and laser principles. The Environmental Science Services Administration (ESSA) plans to have synchronous metsats in orbit by 1972 and by the mid 1970's a full capability metsat will be available. A prototype of the long awaited global, long-range weather forecasting system is expected to be available by the end of the decade.

It doesn't require much imagination to visualize advantages where the weather will be known two, three and even four weeks in advance. Some major examples of advantages include better planning for all types of transportation, aviation particularly; substantially reduce loss of crops from weather changes, reduction of flood and storm damage; optimum scheduling of work force, machinery, and materials delivery at construction sites; and better management of public utilities (electric, gas, phone, water) through advance knowledge of load requirements and efficient scheduling of maintenance operations. Other examples could also be given such as on-location motion picture filming and programming outdoor sports events as well as scheduling the family or company picnic, day at the beach or boat ride.

Among the broadest benefits, aside from general public convenience are saving of life and property, a substantial gain in worldwide crop yield at a time when population expansion threatens the world food supply, and hard economic gains of tremendous scope. Earlier in this thesis an estimated annual saving of $6.75 billion was mentioned if an accurate five-day forecast were available for agriculture, lumber business, surface transportation, retail

marketing and water resources management. Another estimate made by the National Academy of Sciences National Research Council[35] states that the economic benefits of a long-range forecasting system are $2.5 billion in the field of agriculture, construction, transportation, and flood/storm control. One thing seems to be evident on potential savings, applying even the most conservative estimates, the yearly economic return of the global system in several times the amount of all the money expended on metsat research since the first such satellite was orbited in 1960.

The final benefit of long-range global weather forecasting is the most staggering of all and that is the ability to change the weather. Haggerty expresses the possibility very well;[36]

> And once the system /global long-range weather forecasting/ is fully operational, man will be able to realize one of his oldest and fondest dreams - to "do something about the weather." With current and foreseeable advances in the art of weather modification, abetted by the vast encyclopedia of atmospheric knowledge provided by the mathematical model and the metsat reporting system, it appears not only possible but probable that weather conditions can be altered. Scientists feel that it will be possible to change the timing, amount, and distribution of rainfall; to take the sting out of destructive storms by reducing their intensity or directing them into harmless paths; to suppress hail and lightning; to clear fog; to prevent frost; even - though it is farther down the road - to effect large-scale changes of climate.

Mention has been made several times in this thesis about the use of satellites for navigation purposes, specifically the U.S. Navy system called Transit. This area while not of general interest is certainly of general importance and therefore will be treated in greater detail in the paragraphs following.

The Navy navsat system has been in use since 1964 to pinpoint the location of fleet ballistic-missile submarine (FBM) which carries the polaris missile, one of the major components in our nuclear deterrent capability. Before the navsat, navigation errors of two to three miles were frequently experienced in good weather and as much as 50 miles in bad weather. The navsat system provides a navigation fix with

---

[35] Haggerty, op. cit., p. 8.

[36] Id.

errors as small as the length of a submarine. The Navy navsat is for determination of one submarines location so that the missile (if and when fired at an enemy target) will hit, where desired.

Using the accumulated Navy experience as a design departure point, civil agencies are working on a combined navigation and traffic control system for marine and aviation transportation with the capability of surveillance and control of large numbers of craft.

The proposed civil navsat system would have a pair of synchronous (stationary) satellites over each ocean which would become a precisely located artificial star (or reference point) for fixing aircraft and ship positions. The two satellites would send a signal to the craft which would be triggered back to the satellite. Computer determination of the time of signal travel gives the exact distance between satellite and craft. The intersection point of the signals between both satellites and the craft is an exact navigation fix to the craft's navigator and to the land-based traffic control center.

NASA has been conducting navsat tests for several years with the Applications Technology Satellites and several airlines have been conducting satellite to aircraft tests. The results have demonstrated the workability of a civil navsat system. NASA and the Federal Aviation Administration are developing plans for a prototype one ocean system which is expected to be operational for aircraft and ships by 1975.

The Boeing 747 airliner will have a very accurate onboard navigational equipment called the Carousel IV. This system is an automatic inertial system for providing independent navigation capability for the aircraft. Essentially an inertial system senses all movements of the aircraft and integrates this information by an onboard computer into a continuous navigation fix. This fix is constantly monitored and checked against an independent ground control system.

The Carousel IV is a direct example of a double spinoff. Carousel was developed using the knowledge gained from the Apollo guidance and control equipment used on board the command and service module for the round trips to the moon and on the lunar module for the manned landing on the moon. Carousel was designed and built by

A.C. Electronics (now the Delco Corporation). The Apollo equipment was originally designed by the Massachusetts Institute of Technology and build by A.C. Electronics. The Apollo equipment was a design modification of the Polaris missile equipment also designed by MIT. And so the spinoff story is complete from DOD to NASA to civilian use.

The Earth Resources Technology Satellite development is already underway and the first ERTS will be sent into orbit in 1972. These satellites will have a limited capability and will be technical stepping-stones for the earth resources system which has a possibility of becoming operational within this decade. The 1972 ERTS will produce a land-use map of the United States, classify surface geological features for mineral exploration, identify soil features for agricultural purposes and collect information from unmanned earth based devices such as river gauges.

An interesting NASA development in the field of computer programs dissemination has been the establishment at the University of Georgia of the Computer Software and Management Information Center (COSMIC) for the benefit of the business community. Computer programs come to the center from NASA field installations, NASA contractors, DOD, AEC and university research laboratories. They are reviewed for their adaptability to other uses and listed in a quarterly bulletin stating the types available. A computer program is a sequence of instructions on tape telling a computer how to solve a problem or produce desired information using stored inputs and external inputs.

An example of the broad utility of space program software is illustrated by a computer program used in the design phase of the rocket engine that powers the upper stages of the Saturn V launch vehicle. Engineers at Bonneville Dam employed the same basic program in their design of control circuitry and General Foods used it for food preparation research. The University of North Carolina adapted it to public health studies. With modifications for their specific needs, more than 300 American businesses found a use for this one program. A perfect example of space program spinoff.

The impact of the space effort on Communications has been expecially noteworthy. The benefits to society through improved communications are infinite. Communications are the nervous system of organized society and offer a basic tool for economic and social progress. Just as an example, the largest audience in world history, over half a billion people, witnessed man's first steps on the moon and shared with the astronauts their instant observations and reactions to the first manned landing on the moon.

The first communications satellites were NASA's ECHO, Telestar, Relay, Syncom and the Soviet satellite Molneya. The expanded use and operation of the work started by NASA on communications satellites was undertaken in 1965 by the new Comsat Corporation (Communications Satellite Corporation); and by Intelsat (International Telecommunications Satellite Consortium), an international consortium of 62 nations to handle global satellite communications. Intelsat is managed by Comsat.

Current Intelsat satellites have a capacity of 1200 two-way telephone circuits or four color TV channels. Five thousand (5000) two-way circuits are scheduled for next year. In 1960 live TV could not be transmitted across the Atlantic. Early this year satellites provided closed circuit television and two-way voice circuits between the United States and Europe so that 30,000 European doctors could have a three hour transatlantic conference between American doctors in Texas and their counterparts in Switzerland, Germany and Austria.

Communications satellite savings in money are considerable. For example, before satellites, a west coast-to-Japan cable circuit cost $15,000 per month. Comsat now offers this service at $4,000 per month. Comsat provides hundreds of jobs in the urban areas of our country which many say do not benefit from the space program. Satellite relays do away with the necessity for the tall relay towers, 30 miles apart or with the necessity for expensive submarine cables. A satellite channel runs about one-sixth that of a circuit on a submarine cable.

Satellites properly placed in orbit in relation to each other can provide complete global communication coverage. A stupendous feat indeed which is not matched by ground based communications at the present time and cannot be matched except at prohibitive cost.

Representative Jerry L. Pettis of California[37] described a unique use planned for a communication satellite system:

> In a specific agreement with the Indian Government, a later version of this ATS satellite will provide an operational system for instructional use in India. It will broadcast over that vast country directly to special low-cost television receivers. Built and maintained by India, the program is scheduled for operation in 1972. The Indian Government will provide initially programmed information on improvements to local agriculture and on population control. The educational advantages are enormous for this type of system and underdeveloped countries throughout the world will get first hand information on the practical value of such a system. The economic and social value to them of such a system is beyond measure.

The communications experiment in India whereby 5,000 villages will receive direct transmissions from an Applications Technology Satellite (ATS) in synchronous orbit. A synchronous satellite orbits at 22,300 miles. At that height it is orbiting at the same speed that the earth is rotating and so in effect it is stationary with respect to the ground below. From this vantage point the satellite can broadcast or "see" approximately forty percent of the earth, three synchronous satellites can cover the globe with considerable overlap. A simple illustration of how this works would be to take three ice cream cones and a red rubber hand ball. The point of the cone is the satellite and the widest point where the ice cream goes is the earth coverage area of the satellite. Place the widest point of the cones over the ball (which represents the earth) and we now have what looks like a ball with three points projecting from it. This is what complete broadcast coverage of the earth by three synchronous satellites would look like.

The Indian experiment which will last one year is unique in that the satellite would broadcast directly to 5,000 villages. The television sets on the ground will be able to receive the transmission directly. The important thing is that the single satellite transmitter will replace the several dozen conventional ground broadcast stations that would have been required to transmit to the 5,000 villages. A study by one aerospace firm working on direct-broadcast satellites

---

[37] Speech by Representative Jerry L. Pettis, California, Member Committee on Science and Astronautics, Spring 1970, on the subject of space program benefits.

indicates that it is both technically and economically feasible to provide India as early as 1974 with a single satellite capable of linking all of the nation's 560,000 villages. The potential is enormous. With a dearth of teachers and educational facilities, no interconnecting system of TV landlines and insufficient funds to build one, India can use the space satellite as an immediate instructional tool for the uplift of its 500,000,000 people. For a fraction of the cost and about one-tenth the time it would take to build a conventional system, India (or any other nation) can acquire a nationwide communications network.

Some of the benefits include the fact that such a communications network will help knit a burgeoning country more closely together, speed the growth of commerce and technology, and bring entertainment to people who have known little. More importantly, it affords a direct attack on some of the world's most pressing ills through its use as an educational medium. India's planned targets, for instance, overpopulation and low yield per acre of tillable land, are examples of major problem areas susceptible to improvement by mass instruction.

The benefits to society of communications satellites are widespread. Communications are the nervous system of an organized technological society. Good global communications are a vital necessity in the world today. They are the basic building blocks of economic, social and technological progress. The world is witnessing and is in the midst of a global "communications explosion" which will have far reaching effects. NASA has led the already dynamic telecommunications industry into a newer, far more efficient method of providing long distance immediate communication.

A great many other significant, though less earth-shaking "spinoffs" of the space industry have added to daily comfort and convenience.

Housewives are using the new alkali silicate paint developed by space scientists which covers easily with one coat, yet strongly resists fading from detergent washing.

Sealants used on the seams of spacecraft are now used successfully for caulking bathroom tiles.

Students are benefiting from a miniature planetarium made possible by the vast amount of data recently available on lunar and planetary trajectories. This device can determine the relative position of heavenly bodies on any given day in the twentieth century.

Space scientists have even contributed indirectly to the improvement of ladies' undergarments. A laminating technique invented for the production of spacesuits is used by brassiere makers to give American womanhood a more comfortable uplift.

A small company working under contract for NASA and the U.S. Atomic Energy Commission developed a way to form pyrolytic graphite into insulting spacer cups for use in nuclear powered rockets. The technique is now used in machining the same materials into liners for the bowls of tobacco pipes that, as a result, remain cool to the tough throughout the smoke. Retail sale of the pipes has passed a million dollars.

Teflon has become a household word centered in the kitchen because of its application as a non-stick device to cookware. These also are derivatives of the national space and missile programs.

Representative Guy Vander Jagt, Michigan, commented on an international aerospace information exchange system that NASA has implemented.[38]

> An interesting and useful capability that we have developed in the computer information field, which may be a breakthrough in international data exchange, is an American-European computer-based information storage and retrieval system set up by NASA in agreement with the European Space Research Organization ESRO). Supplementing longstanding document exchange procedures with ESRO, the NASA/RECON system provides access to aerospace literature, and is probably

[38] Remarks by Representative Guy Vander Jagt, Michigan, Member, Committee on Science and Astronautics, presented in the 9th District of Michigan, 1970.

> the most advanced in the world. From a computer center in Darmstadt, West Germany, this powerful system serves scientists through remote terminals in Paris and Brussels. Additional terminals are being installed to extend the network. All major NASA field centers are tied into the system which involves a two-way exchange of NASA and European aerospace literature indexes. Nearly 300 governmental, academic and research organizations in some 50 countries participate, furnishing a foundation for development of further advances to serve the world aerospace community. No doubt similar arrangements and systems might be set up for other kinds of information exchange between interested agencies, this promoting further international cooperation on basic levels.

A unique "find" from the Apollo 12 mission is a rock about the size of a small lemon whose age dates back to the formation of the solar system. The 4.6 billion year age of the sample is based upon analysis of isotopic ratios of Strontium-87 to Rubidium-87 and the isotope composition of Strontium in general. 4.6 billion years is the age at which most scientist believe the planets and perhaps the solar system as a family were formed.[39]

Another interesting development which has been made possible directly as a result of having samples of lunar material to experiment with. The material was from the Apollo 11 and 12 landings on the moon. Ten NASA employees have applied for a joint patent on a simple and practical device and process for recovering water and its constituent elements, hydrogen and oxygen, from lunar soil. Oxygen can be used to support life and as a propellant for space vehicles. Calculations show that 100 pounds of lunar soil would yield nearly a pound of water. Fourteen (14) pounds of oxygen are possible from 100 pounds of lunar soil if the necessary iron bearing oxides are first concentrated magnetically.[40]

A space research "spinoff" item of potential benefit to most of the people in the United States is an automative safety device which originated in the shock absorber that is used on the couches

---

[39] NASA Newspaper, "Roundup", Grandfather Rock Among Samples, NASA Manned Spacecraft Center, Houston, Texas, Vol. No. 16, p. 1., June 5, 1970.

[40] NASA Newspaper, "Roundup", MSC /Manned Spacecraft Center/ Tests Show Water, Oxygen Available From Lunar Soil, Vol. 10, No. 2, Nov. 20, 1970, p. 1.

in the Apollo Command Module spacecraft. The shock absorber has been tested by the Bureau of Public Roads in connection with highway guard rails and found that it cuts down a 60 mile per hour impact to the equivalent of a 5 mile per hour impact.[41]

The Ford Motor Company is aiming at incorporating this device into an automobile bumper as soon as possible, perhaps even on its 1972 models. The economic significance becomes evident in two areas, for example the Allstate Insurance Company's announced collision premium reduction of 20% for cars equipped with the new bumpers. The other area is the reduced damage to auto and reduced injury and death to people involved in auto accidents. More than 50,000 people are killed every year in auto accidents and more than 3 million injured. About 10 years ago we in the United States passed the 1 million mark of persons killed in auto accidents. This is more people killed in the United States than all of our wars in history.

Another area where large scale death, injury and property destruction is evident in the United States is in fire accidents. Some 10,000 people are burned to death each year in the United States, and property valued in excess of $2 billion is destroyed by fire every year. On May 6 and 7, 1970 the Manned Spacecraft Center at Houston, Texas held a conference on Materials for Improved Fire Safety. The purpose of the conference was to demonstrate to industry that NASA fire fighting and fire prevention technology is available and that NASA is eager to help bring space developments to the consumer.

[42]The area of greatest initial response at the conference appeared to be in the area of new materials. A Firefighters Association representative asked for help in developing a new Universal Firefighters Suit. One of the large wallpaper manufacturers has already contacted the firms which can produce paper and fabrics which are as decorative as ordinary wallpaper, but non-flammable as well. One of the major airlines has asked NASA to assist in redesigning the interior of their aircraft, both in the cabin and the passenger

---

[41]Excerpts from Speech by George M. Low, NASA Acting Administrator, The Frontiers of Space, Houston, Texas, May 2, 1970.

[42]NASA Newspaper, "Roundup", "What Earthly Good is Space"? Answered in Materials for Improved Fire Safety Conference, Vol. 9, No. 15, p. 1, Houston, Texas, Nov. 20, 1970.

areas. The Air Force Material Command has made the same request for help with redesigning the interiors of their T-39 aircraft.

At this fire conference, Congressman Jerry L. Pettis, the keynote speaker, made this comment which perhaps is indicative of the general NASA philosphy towards making use of space generated technology. He said:

> [43]Become Space Age Converts! Become believers in the social benefits of space spin-offs! Become disciples of space research and development! Be evangelistic about helping NASA find more creative ways to apply the new technology.
>
> If you get a good idea, let someone know who will take some action. If you do, others will too - and the space program will become our "Mutual Fund" of the future, the most profitable investment that man has ever made.

---

[43]*Id.*

Space astronomy had made major advances under the impetus of space research. For example observations of the Sun and other stars are being made in wavelength regions that are inaccessible to astronomers using Earth-based instruments. For example, balloon and rocket-borne instruments have discovered that the pulsar in the Crab Nebula emits powerful X-ray pulses. Each pulse contains as much energy as could be produced by collecting the entire electrical output of our present terrestrial civilization for 10 million years, but this pulsar produces such an X-ray pulse 30 times each second. The study of such extraordinary extraterrestrial phenomena will lead to a new understanding of physical processes that may help us to improve life on Earth.

The dramatic Mariner 6 and 7 Mars flybys have greatly modified our thinking about the possibility of life on Mars. These vehicles transmitted 200 times more data about Mars than were obtained from Mariner 4. The atmosphere of Mars is far more hostile than had been previously thought. Terrestrial life forms could not survive on the Martian surface; the atmosphere is so thin that lethal ultraviolet radiation actually penetrates to the surface. Indications are that oceans have never existed on Mars and that water vapor is present only in vanishingly small quantities.

The prospect of life elsewhere in the solar system and the universe is the subject of much past conjecture and fanciful stories. At the present time, the search for life is a planned NASA program and is quite serious in intent and purpose. The subject of life elsewhere than Earth has been given the name "exobiology". The advent of the space age has finally provided "exobiologists" with an attainable goal - that of obtaining data relevent to the origin, nature and distribution of life in the universe.

To date, with one exception, no reasonable concept of life, other than as we know it on Earth has ever been formulated. The exception is based on the discovery in November 1970 of amino acids in an Australian meteorite. Amino acids are considered the building block or prime requisite for the start of the creation of life. At any rate with our present level of knowledge we are operationally restricted to terrestrial life as a model system, however, it is

necessary to bear in mind the possibility of life forms that are completely alien to our own planet.[44]

The subject of exobiology is an integral part of any planetary study. The origin, nature and distribution of life on any given planet is considered to be inextricably interwoven with the origin and evolution of the planet itself and must be studies in that light.

The goals of exobiology are: [45]

> To obtain knowledge of the origin, nature, levels of development, and distribution of life in the universe, and to develop fundamental theories and models based on this knowledge. These goals require (1) a search for extraterrestrial life and life related chemicals on the Moon and other planets, (2) a study of the early chemical and biological history of the Earth, and (3) prevention of planetary contamination from Earth by effective spacecraft sterilization.

The discovery of life elsewhere in the universe will most probably have a profound effect on many of our social, religious and technological concepts. Depending on the level of evolution obtained by alien life forms, we stand to gain a great deal if our initial contacts are handled with wisdom, skill and understanding.

Now that the end of the Apollo landings on the Moon are in sight, NASA has proposed an evolutionary integrated space program to set the pace for the decades ahead, at least until the end of the century.

Basic programs of this future work include lunar exploration, a space station, a reusable space passenger and freight ship, a manned landing on Mars and unmanned exploration of the solar system.

The lunar exploration phase will include the installation of a space base to house the men and equipment required for exploring the moon. Some of the activities will be to determine if lunar resources can be exploited for use on the moon (deep drilling of several hundred feet will be employed in this phase). Large telescopes will be installed for observation of various points in the surrounding space. A roving

[44] NASA Science and Technology Advisory Committee for Manned Space Flight, Proceedings of the Winter Study on Uses of Manned Space Flight, 1975-1985, Conference Held at LaJolla, California, Dec. 6-9, 1968, NASA Report SP-196, p. 147

[45] Ibid., p. 146.

vehicle initially employed in the Apollo 14 landing scheduled in January 1971 will be utilized extensively for astronaut surface mobility.

The space station will initially be called Skylab utilizing existing Apollo Command and Service Module equipment and Saturn booster equipment for purposes of conducting manned flights of up to 28 days to study effects of long duration space flight on crew and equipment. A second Skylab will result in crew rotation intervals of 4 to 6 months with total mission duration of 16 to 24 months.

The skylab information will be utilized for construction of a space station and then a larger space base. The station will accommodate a crew of 12 and they may be aboard for six month periods. There will be as many as five decks for working and living and equipment quarters and compartments. Missions will last over a ten year period with experiments being conducted in earth resources, oceanology, astronomy, solar physics, pathology, enzymology, botany, physiology, man machine relationships, communications, materials processing, and manufacturing.

The space station will be expanded into a space base by addition of existing modules and the design of special purpose appendages for propulsion, storage and experiments. The space base will accommodate up to 100 men for long duration missions. It will probably have artificial gravity (developed in the skylab and the station operations). One of the major uses of the space base will be as launching platform for missions to the planets and elsewhere. It will be 100 or more feet in diameter.

One of the fascinating uses proposed for the space base will be its use as a manufacturing facility. The absence of strong gravitational fields and the presence of high vacuum in space may make it possible to produce new and greatly improved materials, to manufacture products more precisely, and to process materials in new and different ways. One example is the growth of crystals used in electronic assemblies. The size of single crystals grown on earth is limited by disturbing outside forces or introduction of contaminants. In a very clean, zero gravity environment of a space base, free of earth limiting factors, very large single crystals may be grown which

can be used for large power transistors or optical blanks for lenses of near perfect quality.

A round trip transportation system between earth, the various orbiting elements of skylab, space station, space base is essential to the integrated space program. The transportation system called the "Shuttle" will be used to rotate personnel, carry supplies and deliver experiments and equipment. The key to the design of the space shuttle will be reusability. Early design criteria call for a 100 round-trip capability, a far cry from the one shot capability of the early Apollo Saturn launch vehicle. A tremendous and significant cost saving will result approaching the economics of modern aircraft. Essentially the shuttle will be an airplane designed to operate in space utilizing a rocket engine powered by a chemical or atomic reaction (this version being called the nuclear shuttle). The shuttle would be as large or larger than our latest large passenger aircraft, would have a payload (passenger and cargo) capability of 50,000 pounds, with a cargo compartment 15 feet in diameter and 60 feet long. The shuttle will consist of an orbiter for the mission trip. The orbiter will be carried piggyback to the orbital area by the booster which then returns to the launching area. The orbiter will also return to the launching area (or another airfield) upon completion of its trip.

Another major component of the integrated program is the space tug which will be used for short trips between major elements of the orbiting systems and for descent to the lunar surface. The tug will consist of 3 major modules for crew, propulsion and cargo and will have lunar stay capability and orbit repair and rescue capabilities of other orbiting elements.

The manned Martian mission could take place in 1985. Two ships manned by 6 men each would embark on an 18 month round trip to Mars (with a Venus flyby bonus). The crew would spend 30 to 60 days on the surface of Mars exploring and experimenting. Finally, if conditions were favorable, a semi-permanent base would be established with 48 men on the surface and 24 men in orbit.

The unmanned 1977 "grand tour" of the outer planets is also planned. This will be two flights, each of which will fly-by the planets using a billiard-shot technique of bouncing off their gravitational fields. This unique line up occurs only once every two centuries. This time it will occur seven years from now when the United States will be technically able to accomplish the feat. By ricocheting off the gravities of the outer planets, the spacecraft will pick up enough speed to carry them onward at a great saving of time, fuel and energy. The first mission will be to Saturn, Uranus and Neptune. The second mission will be to Jupiter, Saturn and Pluto. The grand tour will take about nine years to complete, not so much when we know that it would normally take 18 years to get to Neptune and 41 years to Pluto.

CHAPTER III

MANAGEMENT BENEFITS

Analysis of space generated innovations and advances in management systems indicates that their applicability extends beyond current space research, beyond the aerospace industry and into almost all sectors of Government and private enterprise.

Not so glamorous as the new wonders of science, but probably just as important, are the management systems and techniques which were developed for large complex space programs. These are substantially different from the techniques that are so successfully applied where activities involve repetitive production of the same design and marketing to a large number of different customers. Large numbers of highly intelligent, energetic personnel trained in a broad spectrum of specialities must be controlled and motivated. A tremendous number of parallel activities involving different functions, different organizations, and different products, all moving together in accordance with intricate plans for budgets, schedules, performance, and interaction must be tracked. Incipient problems must be identified early and efforts marshalled to solve them. The myriad changes that are an inevitable part of any large-scale complicated effort must be managed. The means must be provided for collecting, processing, and distributing large amounts of information that is complex, diverse, and becomes rapidly obsolete. In learning to manage the vast space program, more efficient systems were generated to handle the program's component parts. Such improved systems are broadly applicable in the management of industries and services.

In an extensive report on the benefits to the economy because of the work done by North American Rockwell, the following statement gives a general overview of the possibilities of using space work management and scientific teams to help solve some of our down to earth problems.

In addition to management techniques and systems, the space program had developed large, very versatile teams of highly trained managers and scientists. These teams, both in Government and industry, constitute a real hope and a major resource for dealing with the emerging massive problems arising from the complexity of our era. Such groups are capability-oriented rather than product-oriented. They are competent to design and implement large-scale systems to help overcome critical shortages of community facilities, critical overcrowding and congestion, critical pollution and accumulation of wastes, and critical changes in the world balance of military power. The technological and management fallout of our programs for space has permitted us to outstrip our European allies to such an extent that they and our government are beginning to express concern about a "technology gap."[46]

In major programs like the Apollo space program, thousands of people performed millions of actions over a time span of eight years, the job of identifying each one of these required actions, its relationships with other actions, and its exact timing, sequence, and responsibility for accomplishment, years in advance was truly a prodigious one. With billions of dollars involved, it was and is also one in which omissions or errors could have been very costly in both time and money.

Representative Mario Biaggi of New York[47] feels that the management expertise of NASA can be used directly or by example to solve many of our big city problems. He had this comment to make:

There is no doubt that one of the major national problems today is how to manage effectively a large urban area. From our limited experience to date, it seems reasonable to forecast that advances in aerospace technology offer great potential for solutions to many urban problems. The potential applications are numerous and range from new approaches in the management of large-scale systems to specific applications in improved construction of homes, schools, factories and office buildings.

---

[46] North American Rockwell Corporation Report, S-21, Space Division, Downey, California, Earl Blount, Dave Alter, W. C. Levering, Space Program Benefits, p. 10.

[47] Speech by Representative Mario Biaggi, New York, Member of the Committee on Science and Astronautics, House of Representatives, Spring of 1970, on the subject of the benefits of the space program.

The management skills required to operate and deal with the large-scale problems of today's cities call for the mobilization of Government, university, and industry teams. NASA has shown how this can be done. A specific example of what I am talking about is the adaptation of the systems approach to the cities' problems in contrast to treating each of them in a piecemeal way.

As one watches television coverage of the mission control center for Apollo, it is not at all inconceivable to visualize that cities of the future will have comparable control centers built around computer capabilities developed in the space program. For example, mayors, city councils, and city managers are becoming increasingly aware of the potential of the systems approach - coupled with computers - in dealing with municipal information systems, transportation systems, general communication systems, police communications systems, land use, and zoning planning.

During his testimony before the Committee on Aeronautical and Space Sciences[48], Dr. Thomas O. Paine, Former Administrator of NASA, requested permission to insert into the record in toto a Fortune magazine article by Tom Alexander.[49] The article mainly discusses NASA's contribution to the nation's managerial capability on a large scale complex effort. Alexander says that the very questions now often raised in criticism of the space effort - "If we can send men to the moon why can't we eradicate pollution (or cure poverty or rebuild cities)?" are tributes to the late President Kennedy's foresight in establishing the manned lunar landing goal to restore the nation's damaged self-esteem caused by the orbiting Russian manned spaceships and the involvement of the U.S. in the fiasco of the Cuban invasion.

Alexander says that the really significant fallout from Project Apollo has been of a sociological rather than a technological nature; techniques for directing the massed endeavors of scores of thousands of minds in close-knit, mutually enhansive combination of government, university and private industry.

[48]Testimony by Dr. Thomas O. Paine, Former Administrator of NASA before the Committee on Aeronautical and Space Sciences on the subject of; Space Program Benefits, April 6, 1970, Taken from a publication of the committee, same title and date.

[49]Fortune Magazine, The Unexpected Payoff of Project Apollo, Tom Alexander, 1969 (July).

He says that this combination of talents, capabilities and organizations is potentially the most powerful tool in man's history. Until now, the only obvious applications for a tool of this sort have seemed limited to something about as massive, imperious and glamorous as space exploration or war. The question now is whether such techniques can be refashioned and turned to other tasks as well, to tasks as overriding in importance and difficulty as, for example, the management of the earth's complex ecological system, of which man is but one segment, and I might add, the critical segment which could throw the entire ecological system into a destructive imbalance.

According to a favorite NASA saying, project management is the art of doing what you said you would. In 1961 NASA estimated they could land men on the moon before 1970 for about $20 billion. The timetable was met at a cost of about $24 billion, very close to the original estimate when inflationary allowances are considered.

By way of contrast, many high-technology programs such as the F-111, the C5A, the SST and the Cheyenne helicopter have overrun their cost estimates by large amounts, slipped their delivery schedules and failed to meet their promised performance goals.

Possibly because of this, space-agency people have been asked to solve problems in other government jobs. NASA's former deputy administrator, Robert Seamans, Jr., is now Secretary of the Air Force. Housing and Urban Development has former NASA Administrator James Webb's assistant engineer, Harold Finger, in charge of Operation Breakthrough, the huge nationwide home-building program. James Beggs, former Research and Development Administrator of NASA, is now Under Secretary in the Department of Transportation and Philip Whitaker who formerly supervised procurement activity for NASA has been transferred to the Defense Department to try to improve the contractual climate between the Air Force and its contractors.

The NASA management approach combines certain advantages of the old arsenal concept of the Army and Navy and the newer Air Force concept that depends heavily on private corporations to manage, develop and build big systems. The NASA approach enhances the total abilities of private and government organizations. The contracting firms contribute

research capabilities, manufacturing facilities, and technical expertise, plus flexibility in staffing for special problems that are economically matched by the civil service.

The NASA role is generally an integrating and directing one, but its lasting contribution to partnership with the American aerospace industry has been to act as a central fund of deep experience and a point of transfer by means of which painfully acquired knowledge in managing and developing complicated systems gets from one company to another.

In January of 1967 the shock of a tragedy was instrumental in welding NASA's government-industry team into its present remarkable form. The Apollo command module fire took the lives of Astronauts Grissom, White and Chaffee. The fire suddenly changed the way of doing business which reach far beyond the extensive technical steps taken to prevent a recurrence of fire. Not only was the entire design of the spacecraft reanalyzed but the manned spaceflight organization as well. NASA came to realize that the intercommunication and relationships with the contractors was not working as well as had been thought.

The early tendency to blame North American Aviation for the fire was gradually supplanted by NASA's realization that the fire reflected a NASA management failure in overlooking an inherent design fault which permitted the locking up of men in a capsule with inflammable materials in an atmosphere of pure oxygen. As a result, NASA and its contractors, whether they willed it or not, were thrown together as allies against the common foes of hostile space and complicated machinery. As Tom Alexander so aptly states it:

> The result is an intimate new sociology of space, a new kind of government-industrial complex in which each interpenetrates the other so much that sometimes it is hard to tell which is which ....[50]

In the closely interdependent operation at Cape Kennedy when preparing a given Saturn-Apollo for launch, all the operations of the various corporations must be interwoven and coordinated in greatest detail. This is accomplished by elaborate schedules that spell out on virtually a minute by minute basis what every contractor will be doing in the rocket stack. Schedules get adjusted in numerous

[50] *Ibid.*, p. 24.

meetings chaired by NASA and attended by all the major contractors. The man who oversees all this activity is Dr. Rocco Petrone (former director of launch operations at Kennedy and now assigned to NASA Headquarters). Each week, for example, he holds a session with the supervisors of the contractor task forces at Kennedy. Actual and potential foul-ups are analyzed for their learning value. From time to time, Petrone or his staff members employ a firm but gentle needle upon a contractor whose slippage or faulty performance threatens the launch schedule.

> [51]The industry teams at Kennedy display a loyalty to the Apollo effort that must be something of a perplexity to corporate heads back home. An example is Grumman's George Skurla, who directs the preparation, checkout and launch of the manned lunar module at Kennedy /Spacecraft Center, Florida/. "Sometimes when I go back up to headquarters at Bethpage", he says, "They ask me who I think I work for, Grumman or NASA. But I say that regardless of the corporate badge, we've got an obligation to the program and to NASA." He has differences with NASA, too, sometimes. "We've got to stand up and call the shots as we see them. They're paying for our experience. The pressure is excruciating - all the managers work under the subconscious strain of something going wrong. NASA hounds us sometimes, but they also perk us up when we need it. In my twenty-five years in the aerospace business, this is the most fascinating job I've ever had - or ever will have."
>
> [52]With much of the same earnestness, Austrian born George Low, the Apollo program manager, /now Acting Administrator of NASA/ speaks of the new government-industry partnership as "a very rewarding experience". One of the original planners of the moon mission, Low is an outwardly gentle engineer who replaced Joseph Shea as program manager after the spacecraft fire. During NASA's post-fire introspection, Low decided that far more openness and involvement in each others affairs were needed between NASA and the spacecraft contractors. On his side Low has granted the contractors unprecedented access to his deliberations. "All the contractor people here know that I conduct no meetings with my own people where they are not welcome, the exception being Monday morning staff meetings. The contractors get involved in every decision concerning the program here. It has taken them a while to get them to believe we really mean it though."

---

[51] *Ibid.*, p. 25.
[52] *Id.*

> The other side of the coin is that NASA insists upon being deeply involved in everything concerning APOLLO that goes on within the contractor's organizations. Not only does NASA have teams working within the contractor plants, monitoring quality, costs and schedules, but once a month Low and other members of his organization fly to both North American and Grumman and spend a long day at each company going over engineering and schedule problems in excruciating detail. Like other NASA managers, Low is now convinced that the moon program, with its forbidding stakes and risks, cannot rely upon normal incentives to assure that schedules and quality standards are met.

An enterprise such as Apollo constantly teeters on the knife edge of managerial disaster. In many different places, many things are going on at once that impinge closely one upon the other such as cost, scheduling, weight, performance and reliability. For example, one extra pound of payload could mean ten extra pounds of fuel. Too many extra pounds of payload could result in exceeding the Saturn V's lifting capability and require the weight be removed from other equally important payload equipment. The undesirable result could be expensive reworking of existing hardware, slipped schedules and the possibility of compromised or reduced reliability.

Tom Alexander[53] describes the NASA organization for Apollo:

> Basically the moon program functions as a "projectized" organization, a concept instituted by Dr. George Mueller (pronounced "Miller"), who replaced Brainerd Holmes in early 1964. A former professor of electrical engineering, Mueller brought some of his managerial ideas from the Air Force ballistic-missile program, which he worked on before joining NASA. Slim, pragmatic, and quietly steely, he stands in stark contrast to both the loquacious, nontechnical Webb, a man given to speaking in hazy generalities, and the erudite, philosophical Tom Paine. (Not the least of the remarkable things about NASA is that it manages to stay intact with so many strong willed individuals operating with so many differing styles.) To aid in the reorganization of APOLLO and to run the day-to-day operations, Mueller was able to borrow the Air Force's Lieutenant General Samuel Phillips, a former Vice Commander of the Ballistic Systems Division and Manager of the highly successful Minuteman I missile program. Phillips, an erect, sandy haired native of Wyoming is notable for his ability to impart meaning to the opaque, alphabet-soupy jargon that has sprung up within the field of project management.

---

[53] Ibid., p. 26.

First developed by the military services in connection with large systems, "projectization" has evolved in Apollo to the point of being a management revolution. It carries to its most elaborate development the "task force" concept now becoming the fashion in management doctrine. Under projectization, a separate Apollo Program Office was established in each of the three government field centers - the Manned Spacecraft Center in Houston, the Marshall Space Flight Center in Huntsville and the Kennedy Space Center at Cape Kennedy - as well as on the premises of the main contractors - North American, Grumman, Boeing, Chrysler, I.B.M., AC Electronics, and McDonnell Douglas. Each program office has positions for such functions as design, schedule, finance, and quality control that parallel those in the main program headquarters in Washington. In effect, these offices form a separate network for command and communication outside the main NASA organization to monitor all Apollo work with respect to schedule, cost, performance, and quality and, of course, to ensure that all the pieces will indeed fit together when they finally meet for the first time at Cape Kennedy.

But the end result of projectization is an inter-woven structure whose lines of responsibility and communication reach out in several directions. It departs from many of the principles of classical management theory, including unity of supervision and responsibility and rigid hierarchies of command. Each of the program offices at both the center and contractor organizations must serve two masters, the Apollo program and the organization itself. In cases of conflict over directives, appeals are brought to Mueller, who is not only in charge of manned space flight, but is also over-all chief of the three centers as well.

If what NASA and industry have learned about management will lead to better ways of solving other large tasks such as pollution, transportation, education, poverty and health, then the "spinoff" benefits of the space program are considerable and a bargain at that.

NASA has two major tools for managing the Apollo program. One is FAME (Forecasts and Appraisals for Management Evaluation) and the other is "configuration management". The heart of FAME is a series of several hundred constantly updated charts dealing with weight, schedule performance, cost, etc.

During design, development and fabrication computers translate the data into trend curves for prediction of future events to enable corrective action. Configuration management ensures that changes are properly instituted so that perturbations are not unknowingly inserted into the spacecraft design. The control is exerted through a hierarchial set of Change Control Boards, running from the manufacturing level to NASA's Washington Headquarters. Rigid rules specify the kinds of changes that can be made in hardware, software, or mission at each level without approval from a higher board. For example, a bolt size change might be changed at the manufacturer-resident NASA office level but the relocation of a fuel inlet might require NASA headquarters approval because it could have an effect on the location of the umbilical arms on the launch tower.

Communications and documentation are extremely important in NASA's management effort. NASA makes extensive and constant use of the telephone, datalink, telex, LDX and formal and informal conferences. The documentation encompasses every technician's task, every test, every lot of every material, every component - all these items and events have a formal document associated with them to fix responsibility on to trace a component or material failure and prevent its reoccurrence.

An impressive technological contribution is reliability. The management philosophy that places overriding emphasis on the safety of the men aboard. It is a design philosophy that requires almost 100% reliability for each part, and further requires "redundancy" or an alternate means of performing a function for every component whose failure could imperil the lives of astronauts on the mission itself.

In spite of all the formal rigid controls the real key to success lies in the dedication, painstaking attention to detail and mutual cooperation. Dr. Thomas O. Paine, Former Administrator of NASA[54] felt that another important class of achievement from NASA's programs is the demonstrated national capability to organize and manage very large, long-term, global technical enterprises and meeting difficult performance goals on schedule and within budget.

---

[54] Paine, op. cit., p. 20.

Dr. Paine felt that the benefit of NASA's contribution to the Nation's growing management competence to accomplish what we set out to do is as great as all the other values combined. He felt that NASA's management techniques could be applied to urban problems. The following excerpts are from a paper by Dr. Paine[55] discussing space age management and the urban complex.

Dr. Paine commenced his speech with the following comment;[56]

> "If we can go to the moon, surely we can vastly improve our cities here on earth." This simplistic but oft-repeated complaint is a non sequitur. Mobilizing bold ventures in space is clearly far simpler than better organizing the extraordinary complex human interactions that comprise a modern metropolis. NASA's spectacular advances in space are undoubtedly exacerbating public frustration with urban failures, but at the same time they are encouraging the nation to tackle its more complex human problems with greater confidence on a bolder scale. If America can go to the moon, it can indeed do much better here on spaceship earth.

Managing the Apollo program is different from running a city, however, NASA's broad management experience does have relevance for urban administrators. NASA's range of management approaches is nearly as broad as the range within an urban complex. This considerable overlap of management demands and similarities and approaches is classified by Dr. Paine as a "spectrum of management" scale. Dr. Paine said;[57]

> Let us begin by examining some of the similarities between NASA and cities. In an obvious way, both are large and complex human systems involving hundreds of thousands of people and billions of dollars. Both involve the dynamic interaction of innumerable individuals, groups, and institutions; both are mechanisms for sensing, integrating, and solving a great diversity of interrelated problems. Each in its own way is a "public" enterprise that exercises public responsibility, requires public support, and must operate in the "goldfish bowl" of public review and criticism.

---

[55] Paper by Dr. Thomas O. Paine, Former NASA Administrator delivered at the National Conference on Public Administration, Miami Beach, Florida, May 20, 1969 titled: Space Age Management and City Administration.

[56] Ibid., p. 29.

[57] Id.

Technology has become the engine of change for human enterprises around which many other considerations are scaled. For NASA technology is deliberately created and utilized. For cities the recognition of technological change is often reluctant. Cities often act like victims reacting to technology, rather than beneficiaries. Technological change and the social change that accompanies it is creating new leadership opportunities for directing new technology and new management capabilities in the public interest.

The NASA organization and urban cities differ in many important ways which sometimes makes the direct transfer to management capabilities difficult. NASA is concerned mainly with physical systems and "hardware". Cities are concerned mainly with human systems and "software". Dr. Paine makes the following comment[58]

> NASA's interests might be thought of as narrow and future-oriented, in contrast to those of cities which tend to be broad and oriented to the past. NASA can define specific, stated, measurable goals, articulate them, and demonstrate obvious success to its public. Cities have at best very general objectives, many of which are undefined and unmeasurable, some of which cannot be stated in any operable way, and are subjects of passionate public dispute. More importantly, NASA's end products respond to, and are tested against, natural laws which are rational, systematic, codified, and well understood, the power of modern science is called in to rectify the situation. Cities on the other hand, have their report card marked against wobbly success standards thinking, conflicting values, loose rhetoric, prophecy and revelation, or in the current vernacular-SOUL. A social theory to guide urban society is nonexistent - or worse!

The main point in a comparison of NASA with a city is that the urban manager like the NASA manager must consider the wide diversity of activities within the total urban complex or space system. Dr. Paine continues;[59]

> For example, the thousands of "old law" tenements in Harlem built to house sweatshop immigrant workers more than half a century ago are utterly obsolete in this age - rehabilitated or not, rent controlled or not - as are the disgraceful neighborhoods in which they stand. The job of replacing them is

[58] *Ibid.*, p. 30.

[59] *Ibid.*, p. 31.

before us. What are the important human values, urban goals, and public expectations here? What new institutional patterns can best achieve the various objectives? What resources will be required over what period? How can the contributions of universities, industry, and government be organized? What approach from the "spectrum of management" is best for each component? How will the required new scientific understanding be acquired through theory and experiment? What technological advances should be fostered and utilized? As the work progresses, how are the experimental results to be fed back to the action controllers? Here is an urgent urban management problem worthy of the nation that conquired the moon. Obviously the job cannot be managed like Apollo, but I believe that NASA's broad experiences in space-age management do have applicability.

In a city a transit system, garbage removal or cable TV service might best be operated by competing private companies, or a single company under franchise or by the city using municipal employees or set up as a non-profit corporation or authority or at a later time be contracted out to support service contractors under periodic competitive bid. Technological change as mentioned earlier will alter the relative desirability of these approaches as, for example, gasoline buses replaces electric trolleys, and kitchen disposals replace garbage cans and trucks. It is felt that very few cities have the managerial structure and resources to take early advantage of technical opportunities, foresee new possibilities and deliberately bring about needed technical advances. Since urban management lags so far behind the need, it can only lead to deteriorating services and soaring budgets.

Dr. Paine concludes his thoughts on the NASA/urban management comparison with four significant points;[60]

> First - The urban manager like the NASA manager, can and should directly manage only a limited part of the complex interacting human enterprise for which he has responsibility. For the important remainder he must structure a ... system to encourage essential contributions from industry, from universities, and from the entrepeneur, the free wheeler, the scientist, the brilliant innovator, the gifted teacher, and other committed individuals.
>
> ....
>
> Perhaps the most difficult task we have is to conceive and establish the appropriate institutional architecture to achieve this.
>
> ....

[60] Ibid., p. 32.

Second - It is the nature of the job for the high-level public administrator to help define and articulate goals in the public interest.

....

From his understanding of the environment, the urban manager can decide realistically what he can manage and where he can lead, identifying those areas of activity which need to be moved toward a different management approach, and effecting the required changes.

....

Third - It is essential to define specific objectives and goals and to relate the resources required to each area of management activity. The planning - programming - budgeting technique, though no panacea, can be helpful here. Objectives should serve as targets for achievement and not be treated as fixed and immutable components. Objectives (like NASA's moon landing) are vital, however, for two purposes:

> 1. They provide a vital focus and communication tool for continuing discussion among the many forces at work in the urban environment.
>
> ....
>
> 2. Goals are also a necessary prerequisite to the use of the powerful tools of systematic management which are being demonstrated and further developed now in business and government.
>
> A vital consideration is creating the appropriate institutional architecture for complex management tasks is a relistic appraisal of the resources required to achieve the goals, and the creation of appropriate organizational mechanisms for close control of these resources.
>
> ....

Fourth - A fatal flaw in a complex human enterprise operating in the modern environment of technical and social change is to freeze its institutional architecture. "Horse and buggy" institutions and jurisdictional boundaries must be overhauled and updated.

....

We should also get to work on a useful social theory.

....

Almost everything that happens in a city happens to all its citizens. It is perhaps fortunate that city residents are inevitably becoming more concerned and involved. This provides the urban manager with a "sputnik-like" opportunity to marshall public concern now into a new commitment to an urban renaissance in America.

....

In California large private companies, mostly aerospace companies, have been asked to consider questions like the control of crime and delinquency. Senator Gaylord Nelson has recently proposed studies similar to those in California on a national scale. In introducing the proposed legislation (S.2662) the Senator noted in part:

> It would be highly in the national interest to begin devoting a portion of the talents and brains of our defense and space industries to other national goals of a great society. This would require no diminution in either our defense or space commitments. We can do both - we can have guns and butter; we can have a moon shot and a national plan for the abatement of pollution; the Polaris project is not incompatible with a new and scientific attack on the terrors of crime. Moreover, the California studies have shown that private firms can help us achieve this objective ...
>
> In fact this capability and brain power already available throughout the Nation is ... a scientific weapon of demonstrated power and a source which represents a high national investment.
>
> Our task is to recognize that we have the scientific know how, and the men to solve almost any problem facing society. Once we understand this, I am confident we will choose to use the resource; we will choose to set our highly trained manpower loose not only on space probes but on down-to-earth problems; we will choose to use systems analysis, the computer, and every modern resource available to us in the quest for progress.

Haggerty[61] feels that the biggest impact of the communications satellite (Comsat) may be neither in TV nor telephony, but in the rapid transmission of data from source to user, by linking together widely separated computers and other data processing equipment. Such systems might have video channels, but in most cases video is not needed; the information can be sent in computer - language and teleprinted in readable form at the other end of the circuit.

A major example of possible use of the Comsat is transmission of management information, inventory and production-control data for example, from a number of plants to a central headquarters. Another

---

[61]Haggerty, op. cit., pp. 4, 5.

example of management information is the transfer of the latest medical knowledge from research centers and great library complexes to outlying precincts where such information is not available. Computer interconnection is not new and was pioneered by the military in the 1950's but the drawback is that existing systems employ costly land-lines. The Comsat can reduce the cost and provide more complete coverage.

CHAPTER IV

ECONOMIC BENEFITS

At its production peak in 1966-1967, the space program involved over 200 universities and colleges and more than 20,000 industrial firms. It employed more than 400,000 people in every state of the union.

In international economics, during a period when our overall balance of payments was weighted against us, one of the offsets was the amount of money the United States receives from other countries in the field of science and technology for patent royalties, manufacturing licenses, computer rentals, and management services. In 1966 we received $1,316 million for these things, and paid out only $137 million for like items. This ten-fold favorable balance is the result of continuing emphasis on research and development and efficient management of new aerospace technology.

Representative Louis Frey, Jr., Florida, had some comments on the economic effects of space research:[62]

> What is in it for the economy and material improvement of our country? What is in it for the individual? The answer is an obvious one to those Americans who are still working in the space program. Admittedly, the number has been reduced from 420,000 in 1965 to approximately 197,000 today, and the total will drop to about 144,000 by June of 1971. In May of last year [1969] 14,369 aerospace firms were doing more than $100,000 in annual business in 1,882 cities in all 50 states and the District of Columbia.
>
> The estimated payroll for the aerospace industry in 1969 was $14 billion. The industry did an annual business of $27 billion that year - and had a $28 billion backlog.

[62] Speech by Representative Louis Frey, Jr., Florida, member Committee on Science and Astronautics, given in the House of Representatives, April 21, 1970.

> Between 1965 and 1971 NASA awarded grants and research contracts for 1,640 programs to 223 colleges and universities in all 50 states and the District of Columbia. The total university expenditures by NASA from 1959 through 1969 totaled $2.7 billion and contributed greatly to this Nation's educational goals by the development of new scientific disciplines, technologies and educational facilities.

Congressman Frey continued with his speech and talked about the "economic multiplier effect."

> It seems apparent we are not, as some have said, "throwing our money out into space." Remember, the money is spent here - in America - for goods and services. In the final analysis, it means jobs, people's salaries. When the normal economic multiplier of five to seven is added, the positive impact of the space industry on our economy is approximately $20 billion each year.

Congressman Charles A. Mosher, Ohio, commented on the interlocking beneficial effects that space research had on our economy:[63]

> I do not believe a reasonable NASA budget is in conflict with or steals from other budget needs. In fact, I believe the NASA program so vigorously bolsters our economy, stimulates our technology, and points to the successful way by which great public problems should be attacked. Its beneficial fallout is so great and so varied, I see it not as a rival but as an essential ally to other positive creature programs.

Of course it is realized that technological and managerial advances will inevitably be reflected in economic advances. American history has shown that the greatest periods of vigorous scientific and technological advances were generated by the open frontier leading to the virtually empty west and the challenge and pressures of major wars.

For many decades the frontier drew Americans westward and stimulated advances in sailing ships and steam boats, canals and railroads, agriculture and farm machinery, electric power and telephony, highways and autos, radio and television, transcontinental pipelines and airplanes. The Civil War and two World Wars accelerated U.S. industrial development in the heavy metallurgical industry, shipping, chemicals, aviation,

---

[63] Remarks by Congressman Charles A. Mosher, Ohio, Member, Committee on Science and Astronautics, in the House of Representatives on April 23, 1970.

electronics, synthetic materials, pharmaceuticals, nuclear power, and other areas.

The space age is now adding an effective new stimulus without an open land frontier and without the waste of a great war. International competition in space has given the world a better view of American and Soviet institutions and their capabilities. Without war, space competition has stimulated advances in both nations in science and the application of new technology.

The Department of State prepared a paper for use by NASA on the effects of the Space Program on America's Foreign Relations. The paper enthusiastically felt that the Space Program was beneficial to the United States. The underlying sentiment of the paper was aptly summed up in the last paragraph quoted below;[64]

> In summary, the success and character of the space program have had an important and highly beneficial effect on our posture in the world and our foreign relations. It has added to our national strength in many ways, and promoted national security. It has provided a medium for significant enhancement of the partnership we seek with friendly nations and for the successful negotiation of agreements with the Soviet Union. Only twenty years ago the space program was a gleam in the eyes of a few men then regarded as visionaries; today it influences the lives of a considerable fraction of mankind, and stands in the vanguard of the new and rapidly accelerating global technologies.

An excellent example of space stimulated technical progress is the impact of new space requirements on the computer industry. Large computer systems of great complexity, flexibility, size and speed are needed to perform functions ranging from automated checkout functions to real time monitoring of space missions, from inventory management to aircraft and spacecraft simulators, from computing planetary trajectories to modeling global weather patterns.

Challenging the best talents of our computer industry by NASA has helped the U.S. computer industry to attain its present dominant world position. Virtually every on-line, direct access commercial computer system in the world today is American, and reflects the space guidance and checkout requirements of a few years back.

---

[64]U.S. Department of State paper, Effect of the Space Program on America's Foreign Relations; U. Alexis Johnson, Wasington, D. C., April 3, 1970.

Dr. Thomas Paine in his address to the Congress[65] described the economic value of the computer industry to the U.S. economy.

> The U.S. computer industry does about $8 billion worth of business a year. It pays the highest average wages of any U.S. industry, is one of the most rapidly growing, and contributes a large positive international balance of trade. You might be interested in reviewing a few statistics here. In 1960 the U.S. exported $48 million worth of computers; by 1965, this has risen to $223 million, and it reached $728 million in 1969. U.S. computer exports have increased over 1,400 percent in the first decade of the space age, and prospects for this decade are equally bright if progress continues.
>
> This impressive record is built on excellence of performance through continuing technological superiority. The economic health and growth of this vital new segment of U.S. industry is creating significant national capital, now and for years to come. NASA is proud of the degree to which our stimulus and support of technological advance has encouraged and assisted the computer industry's growth.
>
> Not only did we get full value in the direct results that the Government paid for, but the entire Nation is benefiting from the economic and technological contributions of this industry. America's investment in the computer industry in the 1960's may well prove to be the most beneficial technoeconomic decision for the second half of the 20th century.

The space and aeronautical work done by NASA has had a similar beneficial effect on the aerospace industry. It is now America's largest manufacturing industry, employing 1.3 million people with $14 billion annual payroll. This industry does an annual business of 27 billion and last year (1969) had a $28 billion backlog. U.S. exports of aircraft and parts climbed from $1.1 billion in 1964 to 2.9 billion in 1969 but does not include airborne electronic systems such as radar, communications and navigation equipment. The aerospace industry is thus one of our great producers of national wealth. America would not have this vital industrial capacity, competence, and output today had we not made continuing technological investments in the past. This will hold true even more so in the economic equations of the future.

[65] Paine, op. cit., p. 11.

In the field of telecommunications new uses are continually being found. Banks, stock exchanges, hotel reservations, cable TV, hospitals, computer centers and other new customers are appearing at an increasing rate. We are in the midst of a global communications "explosion". The newest development that can help meet this demand and increase service is the communications satellite. It can supplement or replace cable, radio or microwave links and can interconnect every part of the world. The communications satellite is far more than a replacement for phone or wireless, it is a new kind of capability.

As an example of proliferation of uses resulting from an initial development, after NASA's initial experiments with Syncom II and III, they were turned over the the Defense Department for their trans-Pacific communications requirements until they could meet these needs themselves. The Defense Department now has its own near-synchronous communications satellites in operation as well as a tactical communications satellite (and a navigation satellite called trasit for Navy use). NASA has just launched the British Skynet and NATO has just launched a communications satellite system. The British and NATO systems were both built in the United States in support of joint Western defense needs. All of these systems trace their technical heritage to NASA's communications satellite programs.

In the field of telecommunications as well as other fields;

> The NASA contribution has been to challenge and stimulate technical advance, forcing new inventions into the market place and making them work. This has a national value without a price tag. In my opinion, it is worth, simply, the difference between continuing national progress and falling behind into a position of second best, never again to catch up.[66]

Some telecommunication statistics are of economic importance and will be mentioned here. In 1960 there were less than 75 million phones in America; in 1970 we have about 120 million. In 1960 18 billion phone calls were made in America, in 1969 nearly 200 billion were made, in other words almost 500 million phone calls are made each day in the United States. The value of the U.S. telecommunications business including service equipment, grew from $22 billion in 1960 to over $47 billion in 1970. The circuit mileage has been doubled every 10

[66] Paine, op. cit., p. 20.

years since 1935.

In the field of information flow processes NASA has taken the lead in developing positive new processes for the documentation and transfer of scientific and technical information to those who can use it. The NASA technology utilization program documents innovations from all NASA centers and industrial contractors which may find use in a wide range of other applications. To date over 18,000 individual technology items have been so identified with over 3,000 documented in the widely used "Tech Briefs", of which 38 million have been sold and distributed.

A recent Wall Street Journal article[67] discussed some aspects of the NASA data bank which files and makes available on request the technology items which have relevance to the economy. A portion of the Wall Street Journal Article is quoted;

> William Ferwalt runs a seven-man company that makes oscilloscopes on the Nez Perce Indian Reservation in Idaho. He wants to know everything he can about oscilloscopes, so last fall he paid $190 for a computer search of the National Aeronautics and Space Administration's technical data bank.
>
> For his money, he got the fruits of five years of oscilloscope research done by Bendix Corp. under Government contract. The data included hitherto overlooked techniques for building a special type of instrument.
>
> Mr. Ferwalt expects to parlay his $190 into $100,000 in sales, thereby doubling his company's business over the next several years.
>
> Ferwalt, Inc. is one of an increasing number of businesses taking advantage of the $35 billion spent on research for the nation's space program. The companies get their information at any of six data dissemination centers designed to open NASA's extensive technical data resources to private industry.

The way the transfer works is for a small fee an entrepeneur can have a computer search made of NASA's extensive technological data banks in his own field of interest, and can then apply the

[67] Wall Street Journal, Space Fallout: Data Banks Containing NASA Research Fruits Help Many Companies; Research of $35 Billion Effort Available at a Low Cost; Lockheed, Litton Use Files; Building a Better Oscilloscope, A. Richard Immel, March 27, 1970.

results within his company to develop new or improved products or services in a minimum time at low cost.

Some additional comment should be made about NASA's program to catalog, store, retrieve and disseminate the vast amount of information that is being generated in the scientific areas. NASA makes available the results of worldwide research and development activities in aeronautics, space and supporting disciplines. NASA's scientific and technical information system contained nearly a million documents. The NASA system includes the Scientific and Technical Aerospace Reports (STAR). STAR is a comprehensive abstracting and indexing journal covering worldwide report literature on the science and technology of space and aeronautics. Publications abstracted in STAR include scientific and technical reports issued by NASA and its contractors, other U.S. Government agencies, and corporations, universities, and research organizations throughout the world. Pertinent theses, NASA-owned patents and patent applications, translations, and other separate documents are also abstracted. Citations and abstracts in STAR are grouped in 34 subject categories.

Additionally, by arrangement between NASA and the American Institute of Aeronautics and Astronautics (AIAA), the publication, International Aerospace Abstracts (IAA), published by AIAA, provides parallel coverage of scientific and trade journals, books and conference papers in the same subject areas as the reports abstracted in STAR.

A description of the purpose of the NASA Scientific and Technical Information is quoted directly from NASA's descriptive publication;[68]

> The NASA scientific and technical information system has been developed to maximize the use of newly acquired knowledge for all men's benefit. It is highly specialized and highly automated primarily to meet the needs of the many participants in the exploration of space, but other government, industrial and academic groups have found the system helpful in a great variety of other endeavors.

[68] Information booklet, The NASA Scientific and Technical Information System, Its Scope and Coverage, National Aeronautics and Space Administration, March 1970.

> Thousands of documents are added to this information bank every month. Many others are rejected to prevent the scope and coverage of this system from overlapping and excessively duplicating the services of other large information storage and dissemination programs. This publication lists the criteria that currently govern decisions regarding additions to the NASA collections.
>
> The rapid advances in science, engineering, and technology applicable to innumerable aerospace tasks - and the increasing erosion of the mechanical, disciplinary, and geographical barriers to the transfer of technical information and data - make it imperative that the coverage of this system be reviewed frequently. So, as much as this publication is a current "table of contents", it is also a guide to those who can usefully suggest adjustments in the scope of the NASA scientific and technical information system to meet its constantly changing needs.

As an example of the technical information program, NASA, in response to my request for literature on the benefits of the space program (which I made to their Scientific and Technical Information Division), provided me with a copy of each of two computer literature searches that had been previously done for a paying user. They were extensive in scope.

NASA Literature Search 9748 titled; "Measuring Benefits of Public Programs", dated September 12, 1969 had 648 citations. As an illustrative example, one citation has been taken at random:

Space and the National Economy. (Space Program in Terms of Benefits to National Economy) Welsh E. C. Conference on Space Science and Space Law U. of Oklahoma, Norman, Oklahoma, June 18-20, 1964.

NASA Literature Search 9175 titled; "Economic and Technological Benefits resulting From the U.S. Space Programs", dated July 10, 1969 had 413 citations. One citation taken at random is:

Some Major Impacts of the National Space Program, Economic Impacts, Stanford Research Institute, Menlo Park, California, Hough, R. W. June 1968.

NASA Literature search 9748 was prepared in part by a new technique: NASA (RECON). RECON is the acronym formed from the words REmote CONsole. It is a direct-access, time shared, information retreival service by means of which individual scientists and engineers may

almost instantly interrogate a central computer to search hundreds of thousands of document citations, with results displayed in seconds on the cathode ray tube before which the inquirer is seated. Search 9748 comprised both printed output from NASA/RECON and printout resulting from a conventional tape search.

Search 9748 is a refinement of Search 9175 which is based on a computer search of the collection of bibliographic and indexing information stored on magnetic tapes at the NASA Scientific and Technical Information Facility. The results are compiled in the form of a computer printout that contains listings of two types of reference citations, viz., technical report citations and published literature citations. Abstracts of the technical reports cited in the printout may be found in NASA's semi-monthly journal, Scientific and Technical Aerospace Reports (STAR). Abstracts for published literature references may be found in the semi-monthly journal, International Aerospace Abstracts (IAA) which is published by the American Institute of Aeronautics and Astronautics (AIAA).

Any individual or organization wishing information on aerospace activities has an unparalleled goldmine of information at their disposal with this NASA information retreival system. It is one more example of benefits from the space program.

Dr. Paine[69] quoted Dr. Lee DuBridge, the President's former science adviser on the subject of the effect of space research on education;

> One hundred years from now the new kind of knowledge obtained in space research will surely have paid untold, unforeseen, and unexpected dividends. Already, the dawning of the space age has impelled Americans to seek to improve their schools. That alone may be worth the cost of all our space rockets.

Dr. Paine[70] felt that the greatest contribution to U.S. Education of space research has undoubtedly been the information academic researchers have received from our direct involvement of the university community in the U.S. space program. What these scientists and graduate students learn in the pursuit of their research feeds back immediately into the

---

[69] Paine, op.cit., p. 35.

[70] Id.

teaching, publication and learning process, thus becoming available to the new student generation and technical community. NASA's university programs include all project-oriented research supported by the various program offices and NASA centers, and the sustaining university program. They are supervised by the Office of University Affairs. The programs emphasize quality research which are useful to NASA and to the colleges and universities as a source of strength.

In 1969, NASA funded about 1,400 projects at some 230 universities, with an expenditure of approximately $115 million. NASA made a special effort to alleviate the recurring funding crises of research projects by providing some forward funding at reduced levels for approximately half of the continuing research projects at the universities.

In the President's Space Report[71] he reports on the space funds expended by the National Science Foundation for the furtherance of educational activities. In fiscal year 1969 approximately $4.8 million was obligated by the Foundation's three education divisions for activities which were, either in whole or in part, related to aeronautic and space sciences. Since many of these awards were multi-discipline in nature - e.g., a project providing training in several disciplines - it is therefore estimated that approximately $2.95 million was awarded in fiscal year 1969 for education in the aeronautic and space sciences.

These funds provided for fellowships and traineeships, upgrading the subject matter background of teachers, training for students, and contributed through a variety of mechanisms to the improvement of education in aeronautic and space sciences in junior and senior high schools as well as institutions of higher education.

The effect of space research on education can be directly assessed in some instances but for the most part there is difficulty in establishing a simple cause and effect relationship. A review of the major influences seems to show that the age of space must be considered as a leading factor. Some of the other major influences are mentioned to put this discussion in perspective. Education has also been affected by the civil rights revolution, urban decay, affluence, poverty, war, fear of an atomic war, automation, the new

[71] President's 1970 Space Report, op.cit., p. 77.

morality and the personal identity crises which seems to have lead to the so-called generation gap.

NASA's long range plans for their education assistance program has been hit by the budget crisis. In 1965, 3132 students were studying for their doctorates in 142 universities in all 50 states under NASA Sustaining University Grants. This figure has steadily decreased to 1,300 in 1966, 800 in 1967 and 75 in 1968. NASA support in educational construction has also declined drastically from a past investment of $44 million in nearly 35 universities to no funds for fiscal 1969.

At the elementary and secondary school levels, NASA's Educational Programs Division gives the nation's teachers a major assist in teaching the basic understandings of Space Age developments. The Division's curriculum supplements have been designed to help teachers relate the latest space achievements to science, math and technical art courses. The Division also conducts a Teacher Services Program to provide space-related courses, seminars and institutes for elementary and secondary teachers. In 1968 NASA education offices served more than 1,250 teacher education programs in the 50 states with an enrollment of more than 37,000 teachers. NASA embarked on these education assistance programs a decade ago because it was clear that any long term success of the space program would be dependent upon the training and assistance provided by educational plants at all levels, from elementary through post-graduate.

An interesting aspect of the NASA effort is the patent and license regulations which are a further aid in the transfer of technology. Historically, a strong protective patent policy advances a nation's industrial economic capability by providing an incentive to inventors, entrepeneurs and organizations.

The NASA patent regulations encourage full industrial use of inventions that result from research and development work performed by employees of NASA and its contractors. The regulations stimulate the making of inventions and provide incentives for their integration into the economy.

Under the Space Act of 1958, all new technology, including inventions deriving from work under a NASA contract must be disclosed promptly to NASA. These inventions become the agency's exclusive

property. NASA may waive all or any part of the rights in the invention to the contractor, however, if it is in the public interest to do so.

When a NASA contractor makes an invention and subsequently receives a waiver from NASA, the company obtains title to the invention, subject only to the reservation that the Government may have a non-exclusive license to use the invention. The recipient of the waiver is required to reduce the invention to a commercial form within a reasonable period of time and to file a patent application, or the waiver will be revoked.

To encourage the earliest possible commercial use, all inventions owned by NASA for which a patent application has been filed, or that have been patented on behalf of NASA, are available for royalty-free license by American firms. If the invention is not reduced to commercial form within two years after a patent has been issued, NASA will make the invention available on an exclusive basis in order to stimulate interest in using it commercially. A few inventions are also available for licensing by foreign firms.

On December 31, 1962 the U.S. Government owned 13,671 patents and the number was increasing at the rate of about 1,900 annually. A survey disclosed that around 10 percent of the inventions assigned to the Government also reached a stage of commercial utility.[72]

In January 1963 NASA reported that its work, conducted both in Government laboratories and private facilities, had led to 786 inventions. By August 1964, the number had increased to 2,500; and by May 1965 that number had doubled to 5,000.

The space program has a significant multiplier effect on our economy and society in general. Inevitably, we always come back to the dollar questions: What has it cost? What should it have cost? Would the money have been better not spent, or expended on other things "here on earth"? Without repeating the obvious fact again that indeed all NASA's dollars are spent on earth, the reply to these questions seems to be that the country is getting its moneys worth and must press vigorously forward both in the space program

[72] Holman, Mary A., "Government Research and Development Inventions - a new Resource?", Land Economics, August 1965.

and here on earth. Space research and earth-bound expenditures are not mutually exclusive, but mutually supporting enterprises.

The United States has been spending its tax dollars at an ever-increasing rate for programs to effect social change; in schools, in welfare programs, in poverty programs and has been spending tax dollars at a decreasing rate in NASA to effect technological change.

Money spent on social programs involves the redistribution of existing resources, money spent on space research involves the creation of new resources. The social account is far larger and growing rapidly. The growth alone in 1969 in social programs was the dollar equivalent of two whole NASA yearly programs. The fiscal year 1971 budget proposal was to increase the social programs by $2\frac{1}{2}$ NASA's total budget.

Our space effort over the 1959-1969 decade has cost less than one-half of one percent of our gross national product and in return it has made a major contribution to the growth of our GNP from $440 billion in 1958 to $900 billion in 1969. The $450 billion growth in our GNP is probably one of the principal factors that has made possible our expanded social programs.

Adding up the Federal budgets from 1959 to 1969, we find that the United States has spent $1.4 trillion and of that figure, the NASA program has cost $35 billion or only $2\frac{1}{2}$ percent of Federal spending. It would seem that the many benefits to the United States and in fact to the world far outweigh the sum spent on the space program. Time and again in doing the research for this thesis the same expression has been used by different people and I will repeat it here in paraphrased form because of its relevance; "Let it not be said that we /Americans/ know the price of everything and the value of nothing". The President's Annual Report on the space program[73] shows that over a period of 15 years and through the end of fiscal year 1970 the United States will have spent more than $57 billion on all of our space programs for all federal agencies, NASA, DOD, AEC, Commerce, Interior, Agriculture and the National Science Foundation.

[73] Aeronautics and Space Report of the President, Transmitted to the Congress, p. 105, Appendix F-1, January 1970.

The nation's economic effort over the past twelve years totals over $8 trillion. Of this, taking inflationary trends into account, more than $2.4 trillion was real growth over the 1959 level. Various estimates indicate that approximately 50% of growth in productivity is attributable to the flow of new technical knowledge into the economy. That knowledge comes from research and development investments. A perusal of breakdown charts for R&D allotments[74] indicates that 25% of the nation's total research and development was carried out under the space program for the period 1954 through 1966.

The space program could therefore be considered responsible for a major part of the new technology which creates wealth and productivity. This is one way to estimate the force for progress exerted by the space program.

One measure of space program benefits in approximate dollar values might be the growth in national wealth and productivity. The gross national product has more than doubled since 1959, going from $469 billion to $960 billion in 1969, an increase of over 100%. In 1947, the productivity index for manufacturing as shown in the President's 1970 Economic Report,[75] was around 72; twelve years later it had grown to 96, a 26 point increase. During the next period the growth went to 145, an increase of 47 points, or nearly double the earlier rate of growth.

Dr. Paine in reflecting on this growth in the rate of the productivity increase said:[76]

> This is a reflection of technology moving into high gear - and space has been a driver of the advanced technologies. We do not and cannot claim that space alone has created all the new productivity we enjoy today; we can say intuitively it would have been significantly less without the dynamic leverage of a space program.

I would like to give some statistics on the number of firms involved in the long completed Gemini Program, the two man orbiting spaceship which was the predecessor for the Apollo Project.

---

[74] Federal Funds for Research, Development and Other Scientific Activities, Fiscal Years 1964, 1965 and 1966, Vol. XIV, National Science Foundation Publication No.: NSF 65-19 1965.

[75] President's 1970 Economic Report to the Congress.

[76] Paine, op. cit., p. 71.

[77] McDonnell Aircraft Corporation, prime contractor for the capsule, had 3,196 subcontractors and uncounted suppliers to the subcontractors. Martin Co., responsible for the Titan II launch vehicle, had an estimated 1,500 to 1,800 companies supplying services, parts and materials. The subcontractors ranged in size from General Electric Company to the Blake Rivet Co., a firm with 60 employees that made the special titanium alloy fasteners used in assembling the capsule. The suppliers ranged in technology base and orientation from IBM to the David Clark Co., a brassiere and girdle manufacturer that made the space suits.

[78] Mr. James J. Haggerty, aerospace writer, made this comment on the economic benefits of the space program:

> And they [space program benefits] offer economic returns of a very significant order. Existing estimates, admittedly conservative, warrant the prediction that, by the end of the decade, the direct economic benefits stemming from space-originated technology will far exceed the anticipated annual funding for space research.

[79] Haggerty makes an interesting economic point about the Communications Satellite Corp. (Comsat), the American member of International Telecommunications Consortium (Intelsat). Comsat is a privately owned company which did not exist six years ago, now has 132,000 shareholders, total assets approaching $300 million and annual operating revenues of about $45 million. He feels that impressive as these facts and figures are the Comsat has barely scraped the surface of the lode. In hardware development are new types of satellites that offer exciting potential for the future. At any rate the important fact is that space research has generated an entirely new segment of the communications industry.

Haggerty's economic analysis of the savings accruing in the North Atlantic by reducing required aircraft distances from each other by utilization of the navsat;[80]

---

[77] Richard L. Lesher, Assistant Administrator for NASA Technology Utilization, George J. Howick, Director, NASA Technology Utilization Division, Assessing Technology Transfer, NASA publication SP-5067, 1966, Washington, D. C.

[78] Haggerty, op. cit., p.3.

[79] Ibid, p. 4.

[80] Ibid, p. 9.

> Because of navigational shortcomings, traffic control regulations demand a 120 mile-lateral separation of aircraft as an anticollision measure. This means that, when a number of planes depart a terminal within minutes of each other, only one of them can take the direct, shortest-distance-between-two-points route. The second [aircraft] must move out 120 miles to one side of the direct course; the third 120 miles to the other. The fourth and fifth airplanes must fly 240 miles off course, and so on.
>
> Aside from longer travel time for the passenger, such directional efficiency costs the airlines in increased fuel expenditures. It is estimated that extra costs run from $30,000 to $50,000 per year per airplane, which amounts to a very substantial figure for airlines operating large fleets. The satellite system can reduce required lateral separation to thirty miles at a dollar savings for the North Atlantic above estimated at close to $20 million a year.

The economic benefits of navsat to surface shipping due to the number of ships involved could be substantial. Ship operations currently cost from $1,000 to $4,000 per day while at sea. There are more than 3,000 ships of more than sixty countries reporting to the existing traffic control center and probably a greater number of non-reporting smaller craft such as yachts and fishing boats.

Precision navigation (aside from safety) is a money saver in fuel costs and reduced time at sea. Direct home office to ship contact offers greater efficiency in scheduling and routing and logistics in general. The prevention of collisions offers savings far beyond damage costs. In the oil-shipping industry for example efficient operation requires tight scheduling of ship dockings and oil flow. The removal of a single ship from service due to collision damage can cause a temporary shutdown of an oil field with considerable monetary losses resulting.

A considerable comfort to persons involved in ships or aircraft in distress will be the greatly improved capability to locate a downed aircraft or ship in trouble. Elimination of the search phase of a rescue operation because of precise position knowledge of the search object will save many lives and much suffering.

A recent report prepared by the Maritime Administration for the Joint Navigation Satellite Committee predicted the annual savings that might result by 1975 if automation of ship navigation (utilizing a navsat system) is achieved.[81]

	Navigation Savings	
	Maximum (millions)	Minimum (millions)
U.S. ships (1,000)	$1.4	$0.6
U.S. ships (Atlantic)	1.0	0.4
Foreign ships (17,000)	7.0	3.4
Foreign ships (Atlantic	5.2	2.2
World ships (18,000)	9.2	4.0
World ships (Atlantic	6.2	2.6

A search and rescue satellite system incorporated into a navigation satellite and traffic control satellite system could effect the following savings in search and rescue operations according to an IBM report made for NASA[82] titled "ORL Experiment Program - Communications and Navigation," February 21, 1966.

	Annual rate 1964		Estimated Savings (millions)	
	Occurrence	Cost(millions)	1980	2000
Medical Assistance	1,600	2.83	4.35	8.13
Ditchings	84	4.97	19.78	35.80
Fire, Collision, man adrift	1,250	2.46	3.78	7.07
Total	2,934	10.26	27.91	51.00

Finally, the one important factor in the search and rescue operations is the value of saving a human life for which no dollar amount can be assigned. It is U.S. policy to normally save a life no matter what the cost. It is to be expected that a saving of life will also result from a search and rescue satellite capability.

[81] NASA Report SD-142, A Survey of Space Applications ... "for the benefit of all mankind." Office of Technology Utilization, April 1967, Washington D. C., p. 122.

[82] Ibid., p. 127.

The Earth Resources Technology Satellites (ERTS) that have been discussed earlier in this thesis will provide vast potential benefits. NASA has calculated that an earth resources survey in the United States could reduce agricultural losses by ten percent. Dollar estimates of $400 million could be saved annually in crop losses; increased meat output is valued at $350 million annually due to early detection and correction of nutrient-deficient rangeland; and $100 million a year in agricultural land saved from floods. Even looking at these limited estimates if one were to consider worldwide gains on a global basis, there would be an economic value of billions of dollars per year.

Under the COSMIC program of computer software dissemination, NASA has provided 20,000 software items to interested users. The cost is kept low, from $125 to $1,200 per program and a COSMIC customer can get a software package for from one-half to one-tenth the cost of developing a similar program from scratch. COSMIC was started in 1966 but early results indicate it may become a big area of benefits accruing from the space investment.

The multiplier effect of space research spending on the economy has been mentioned several times in this thesis and it is now time to briefly explain and discuss it.

The simple multiplier theory of economics states that each dollar change in investment leads to more than a dollar - i.e., to a "multiplier" change in NNP[83] /Net National Product/. This increase in national income will be by a multiplied amount greater than itself which is easily computed by either an algebraic or arithmetic formula. Investment spending with its subsequent effect upon increased employment like any other independent shifts in governmental, foreign or family spending - is high powered, double-duty spending. This amplified effect of investment on income (and therefore jobs) is called the multiplier doctrine; the word multiplier itself is used for the numerical coefficient showing how much above unity is the increase in income resulting from each increase in investment.

To give a numerical example. If a $10 billion increase in investment causes an income increase of $30 billion, the multiplier

[83] Paul A. Samuelson, Economics, 8th Edition, McGraw-Hill Book Company, p. 208.

is 3. If the increase were $40 billion, the multiplier would be 4. The multiplier is therefore the number by which the change in investment must be multiplied in order to present us with the resulting change in income.

Samuelson[84] gives a simple example to illustrate the multiplier effect. He says that if we hire unemployed resources to build a $1,000 garage, there will be a secondary expansion of national income and production over and above the primary $1,000 investment. If the carpenters and lumber producers get a total of $1,000 income and if they have a marginal propensity to consume of 2/3's, they will spend $666.67 on new consumption goods. The producers of these goods will now have an extra income of $666.67. If their marginal propensity to consume is also 2/3's, they in turn will spend $444.44 or 2/3's of $666.67. This process continues with each new round of spending being 2/3's of the previous round.

Thus, an endless (although dwindling) chain of secondary consumption spending is set up by the primary investment of $1,000. It adds up to a finite amount either by grade school arithmetic or high school geometric progression. In arithmetic we add $1,000 + 666.67 + 444.44 + 296.30 + 197.53, etc. to get finally a total of $2,999.999 or $3,000.00

The size of the multiplier depends upon how large the marginal propensity to consume is versus the marginal propensity to save. If the MPC were 3/4's, the multiplier would be 4. If the MPC were 2, the multiplier would be 2. It can be expressed in terms of MPS also. If the MPS were $\frac{1}{4}$, the MPC would be 3/4's and the multiplier would be 4. If the MPS were 1/3rd, the MPC would be 2/3rds and the multiplier would be 3.

Using the geometric progression, the formula is:

$$1 + r^{*} + r^2 + r^3 + \ldots. + r^n + \ldots = \frac{1}{1-r}$$

$^{*}r$ = MPC

The simple multiplier is always the upside-down or reciprocal of the marginal propensity to save. The simple formula is:

[84] Ibid, p. 215.

$$\text{Change in income} = \frac{1}{\text{MPS}} \times \text{change in investment}$$

$$= \frac{1}{1\text{-MPC}} \times \text{change in investment}$$

Finally we should say that the greater the re-spending, the greater the multiplier. The greater the saving at each round of saving, the smaller the final multiplier.

I have spent a great deal of time explaining this simple effect because it works backward as well as forward. The increase in spending on space research with its resultant increase in employment has an upward multiplier effect. If space research is cut back as is now the case, there is a downward trend in the multiplier and many people as well as the nation are affected.

Summation, Re-capitulation and Additional Information on Economic Benefits of the Space Program

In this concluding section of Chapter IV some additional dollar figures of estimated savings due to space applications will be presented. Also, some information previously discussed may be rephrased again. The information presented may be cryptic but is purposely done this way in the interest of brevity.

Communications An RCA study of TV broadcast satellites in the summer of 1962 used India as an example and determined that a satellite broadcast system would require only 20 percent of the cost required by existing methodology for establishing a ground-based broadcasting system with similar user coverage.

In May 1966[85], Mr. Vincent Rock, in a speech delivered at the AIAA Communications Satellite Systems Conference stated that:

> Satellite educational and informational television is leading the edge of a trillion dollar market for communications and educational systems. This market is to be found among the 2 billion people of the developing nations of Asia, Africa and Latin America.

In another speech, on the same conference, Mr. R. Burns presented an econometric analysis of a satellite system for educational TV, considering several countries. For India, he estimated that the total annual cost for the space-ground system would be $10.43 million.

[85] loc. cit., p. 21.

Using an estimated 89 million students, by 1970, the annual cost per student would be a phenomenally low 12 cents.

Earth Resources There are many specific examples in agriculture and forestry in which the application of remote sensing techniques are expected to reap substantial economic benefits. Cotton production on a world wide basis could be increased by the use of a remote sensing (via satellite) of soil moisture conditions to establish irrigation times. An increase in cotton yield of 10% would amount to an annual economic benefit of more than $100 million.

Weed infestations of croplands in the U.S. cause an estimated loss of $3.8 billion.[86] Remote sensing techniques (via satellite) for locating and assessing weed infestations could result in economic benefits of $300 - 400 million per year if only a 10-15% reduction could be achieved in losses due to weeds. Similar savings for insect and crop disease detection could be realized.

Cattle production could be increased in the U.S. if satellite detection were provided of nutrient deficient areas, overgrazing, brush and weed infestation, and other range management problems. If a 10% increase in calves (by 3.5 million) resulted, this could mean an annual extra income of $350 million.

Floods cost an annual loss of $1 billion in the U.S. about two thirds over agricultural land.[87] An annual reduction of 10% in flooding losses could save $100 million. Satellite sensing could locate and identify inadequate surface cover, uncontrolled erosion and other watershed problems. It should be noted that the total existing capital investment in water resources facilities of all types in the United States is about $235 billion.[88]

The cost of a national forest inventory of the 508.8 million acres of commercial forests in the U.S. is $10.7 million. Satellite sensing could reduce this cost considerably as well as permit a reduction in the area of forests damaged or destroyed by fire. Timber production increase by detection of nutrient deficiencies, insect and disease infestation could produce economic benefits of tens of millions of dollars.[89]

[86] Crop Research Publication ARS 34-23, Department of Agriculture

[87] Water Facts, U.S. Department of Agriculture Report, 1957

[88] Ibid., p. 60.

[89] loc. cit., p. 41.

The world's undeveloped mineral resources are large enough to support future demands only if imaginative new ways are found to discover, extract, and effectively use such resources. Satellite sensing of mineral deposits could duplicate for example the Canadian airborne finds of the Manitoba mickel deposits and the base metal in Ontario. These two deposits alone are worth several billion dollars. In Missouri aerial surveys discovered iron ore at 1,300 feet below the surface presently valued at $2 billion. Satellites may discover even deeper deposits masked by surface features.

To map the entire earth's surface by aerial photography, it would cost $174 million based on $3 per square mile for the 58 million square miles of land surface. The cost figures are substantiated by a 10 year record of contract purchases for aerial mapping photography. Satellite photography for the same purpose would cost approximately $17 million. The value of more accurate maps to the U.S. would amount to approximately $680 million annually, and applied on a global basis could exceed $10 billion.[90] It should be noted that less than half of the world has been adequately surveyed.

Satellite sensing for collection of oceanographic data for construction of future U.S. sewage treatment plants could result in savings of $80 million annually in construction and operating costs.[91] The satellite collection of oceanographic data for improving ship routing techniques should effect a considerable saving of the estimated $5 billion shipping bill (by 1975) and the estimated $5 billion other non-military activity at sea. A ship with an operating cost of $3,000 per day can save $1,500 with a 12-hour time saving due to improved routing.

In the area of long-range weather forecasting, in addition to what has been reported elsewhere in this thesis, a further breakdown of estimated savings is noted below as provided by the National Academy of Sciences - National Research Council.

[90] loc. cit., p. 53.

[91] loc. cit., p. 67.

Weather Forecast Savings

Type of Activity	Annual Worth (millions)	Annual Savings (millions)
Flood and Storm Damage	$ 280	$ 70 - 140
New Construction	59,000	1,000
Fuels and Electric Power	40,000	500
Fruit - vegetable production	3,200	500
Livestock production	9,000	450
Total Saving	...	2,500

Cloud seeding as a means of increasing rainfall and dispersing fog is being increasingly considered. Space vehicles are being considered as the delivery vehicle for the seeding agents. The economic benefits have been determined for a Pacific Coast public water utility, if precipitation could be increased by 10%, it would be worth $200,000 to the large watershed in question. An airline has estimated reduction in operating expenses from fog dispersion were worth at least 5 times seeding costs.

If hurricane intensity could be altered or changed or the path changed, the $250 million annual losses due to hurricanes could be reduced by more than $80 million.

In the area of air pollution, satellite sensing will play a very important role. The economic issues involved in air pollution are on a truly impressive scale. Even without attaching any monetary value to the time lost from work and shortened life span due to pollution, the strictly economic damages on that account in the United States have been estimated in billions of dollars annually.[92]

What is readily apparent from all of the above figures is that large amounts of data can be collected from satellites at an exceedingly low cost and can cause enormous economic benefits to the nation and to the world.

[92] loc. cit., p. 108.

CHAPTER V

SUMMARY AND CONCLUSIONS

During Dr. Paine's testimony[93] an interesting discussion took place between Dr. Paine and Senator Margaret Chase Smith of Maine regarding NASA's plans for presenting space benefits to the public;

> Senator Smith of Maine. Thank you Mr. Chairman. [Senator Clinton P. Anderson, New Mexico] Thank you Dr. Paine for a very comprehensive statement. I find it very interesting and I am sure all of those in attendance at the hearing this morning find it so.
>
> I do agree, however, with the chairman, that we are not getting the actual benefits across to the public. This may be a beginning. I thought from our conversation at the previous hearing when we discussed this matter that you hoped to have a plan to present to us as to how you are going to get all of these accomplishments and benefits out to the public. I note you say in your statement that you think your agency has done an unmatched job of public education in bringing the facts of our highly technical space program to the general public. I think you have with regard to technical facts. But it is not the technical facts that we were talking about the other morning. It was the practical benefits which the layman can understand that will help us get across to the public and to the Senate the need for this program. You apparently have not come up with such a program.
>
> Dr. Paine. Well Senator Smith, we are indeed taking this on as a very high priority item. I don't have a new program to report to you this morning. The very fact that the committee has requested these hearings has caused us to reexamine the degree in which we are effectively telling this story.

[93]Paine, *op. cit.*, p. 53.

> And although I did say and I believe that we have done a fine job in getting this highly technical message across to the people as to what is going on in the space program, at the same time I agree completely with you that the story of the benefits from space to the man in the street and to the public and to the Nation is the hardest part of our entire communication problem. It is the part that very definitely should be receiving now new emphasis on our part.
>
> I am not satisfied with that part any more than you are. It is a very difficult story to tell and we certainly must find better ways to do it.
>
> Senator Smith of Maine. Well, if you don't, we won't be able to continue to sell the program to the Senate and to the Congress and that to me is very essential if this great program is to continue in the future.

Dr. Paine made a telling point in a philosophical statement[94] about the method to be utilized in accomplishing national goals;

> Now I think there is one other point which I mentioned briefly in my testimony but which I would like to mention again, and that is that one of the impressive things about the space age in the last 12 years that really puts the lie to those who claim that we have to radically restructure our society today is the fact that NASA was able to work within the great flexibility of existing U.S. institutions. We didn't change the civil service laws in order for NASA to go to the moon. We didn't change the fundamental structure of our universities, or of our free enterprise system. All of this was done within American institutions and those who say today that in order to make America move forward to the future, we have to tear things down I think need only look at the successes which NASA has had working within the system as a vivid demonstration that this country has the flexibility within its institutions to accomplish anything which the people of this Nation decide they will accomplish.

During the course of Dr. Paine's testimony[95] an interesting comment was made about people with lack of foresight by Senator Carl T. Curtis, Nebraska;

---

[94] Ibid., p. 63

[95] Id.

> Incidentally, I am not too disturbed about individuals questioning the value of the space program. A brilliant young lawyer here working for the Government who is an attorney for the Committee on Rules and Administration, Mr. Burkett Van Kirk, comes from my state. His grandfather was the distinguished U.S. Senator, E. J. Burkett from Nebraska, who preceded me in the House of Representatives for the First District many years before, and then served in the Senate.
>
> At the time the airplane was being developed, he journeyed from Washington to watch a demonstration of the airplane as a member of the Military Affairs Committee, came back and signed a report and said it was a very interesting experience but it would have no military application. And it has been the source of considerable amusement since then

The objectives of the national space program can be defined as the expansion of human knowledge through space exploration, the development and operation of space systems, the application of space science and technology to problems on earth, and the maintenance of national security.

As this thesis has tried to develop, in working toward the above objectives, the space program results in the creation of wealth through the advancement and dissemination of new scientific knowledge and new technical developments. It is very difficult and it may not be possible in view of our imperfect understanding of the interaction of all social forces to measure the output that is directly related to space investments of the last 10 or 12 years.

Representative Richard L. Roudebush of Indiana commented on the overall aspects and importance of the space program to the United States.[96]

> We are in the age of space whether we like it or not, and there is no turning our backs to it. To do so would mean leaving the space arena free and open to other, probably less friendly, powers who would have no qualms whatsoever about using the power thus derived toward their own ends and not necessarily to our benefit.
>
> ....
>
> History tells us that nations that have paced the world remained on top only so long as they had the vision to develop their technologies and their resources. Ancient Greece, the Roman Empire, and sixteenth-century Spain were all world leaders; that is, as long as they kept developing their technologies, but when those great empires began to concentrate their energies exclusively on internal problems they let their technologies slip and the empires toppled from the position of world leadership.
>
> ....
>
> Another residual value is the pride in our accomplishment. This should not be undervalued. Neither should the good will that it has created throughout the world. In a decade marked by war it is certainly a good legacy to leave for the 1960's. An American footstep and the American flag is on the lunar surface as a permanent demonstration of our ability to accomplish the impossible.
>
> ....
>
> Why space? Space because if we give in now to the temptation to slack off on scientific research and development, we will no longer be the most powerful nation with the highest standard of living. Instead we will live by whatever generosity and whatever grace may be allowed us by the nation, who, by its vigorous program of science and technological advancement, takes our position.

---

[96]Speech by Representative Richard L. Roudebush, Indiana, Member of the Committee on Science and Astronautics, titled: Why Space, given in the 5th District of Indiana, June 1970.

A good summation of the benefits that accrue to a society was made by Dr. J. Bell, Director of Reliability, A.C. Electronics, in a paper by North American Rockwell.[97] Dr. Bell said:

> It's foolish to underestimate the push industry receives from urgent national needs and goals. We saw what World War I did for airplanes. It lifted the airplane from a country-fair attraction to an entirely new concept of warfare and transportation. Look at radar. Before World War II, radar was on a slow burner. Then the war rammed the needs for radar up forward and the result has been an entirely new industry, television. American industry has always been stimulated by national goals, just as we've been pushed forward by the needs of the moon program. We needed that goal, that timetable, that concerted national effort....

Representative Fulton of Pennsylvania feels that perhaps the greatest spinoff of all from international cooperative space exploration might in the ultimate be world peace.[98]

> War has been a way of life on earth for many centuries; it has been mankind's principal means of meeting his will to contest. Now, for better or worse, our civilization has reached another epochal extension of mankind's horizon from earth into outer space. Our nation was not alone in bringing it about, and we cannot stop it; we can only participate, preferably as a leader.
>
> Nations no doubt will always engage in competition with each other in many ways - economically, scientifically and culturally. But given the universe as an arena, with a potential of consummate achievement, it is not beyond the realm of conjecture that nations could turn from violent conflict on earth to peaceful contention in space. This is not a prediction; at this stage it is just a concept - one that can become a new and greater goal for all mankind.

---

[97] Blount, op. cit., p. 40.

[98] Fulton, op. cit.

Dr. Paine summed up his Congressional testimony[99] in a succinct statement which will also provide one of three concluding statements of this thesis:

> The future is far more difficult to predict than the past is to analyze, but as space exploration and applications mature and as new technologies find ever increasing uses, I feel that the economic returns we will measure in the second decade will continue to be in large multiples of their cost. This ignores the immeasurables - I can place no dollar value on national security, on a stable international scene, on lives saved, on knowledge gained, on national self-confidence and pride. Yet all these and more are already the fruits of our past investments.

The second concluding statement is quoted from President Nixon's Space Report to the Congress;[100]

> Our space and aeronautics program has benefited this Nation in many ways. It has contributed to our national security, to our educational, transportation, and commercial strength, to our scientific and medical knowledge, to our international position and to our sense of the dignity and capacity of man. And the story is only beginning. We have made long strides into the future during the past year; now we must build on those accomplishments in the coming years and decades.

[101]The third concluding statement is by Haggerty who eloquently sums up his article on space program benefits by saying;

> Space enthusiasts are fond of asserting that the people of the twenty-first century will look back upon the United States venture into space and declare it to be the best investment in the future ever made by any nation. That seems very likely. But from the evidence at hand, even those of use who cannot expect to see the next century may be able to say as much - within this new decade.

---

[99]Paine, op. cit., p. 71.

[100]President's Space Report, op. cit., message of transmittal.

[101]Haggerty, op. cit., p. 15.

BIBLIOGRAPHY

Books

Samuelson, Paul A., "Economics," College Textbook, 8th Edition. McGraw Hill.

Periodicals

Alexander, Tom, "The Unexpected Payoff of Project Apollo," Fortune Magazine, July 1969.

Anders, William, "The Moon, the Earth, and the Future," Boys Life Magazine, May 1970.

"Artificial Sight Called Possible in Future," The Seattle Times Newspaper, May 18, 1970.

Butler, Sue, "The Microscope Came From a Useless Hobby," Huntsville News, Huntsville, Alabama, August 17, 1970.

Dighton, Ralph, AP Science Writer, "TV May Give Sight to Blind - Camera May Fit in Eye Socket," The Daily Argus Newspaper, Mount Vernon, N.Y., November 10, 1969.

"Grandfather Rock Among Samples," Roundup, NASA Manned Spacecraft Center Newspaper, Houston, Texas, June 5, 1970, Vol. 16.

Gregory, Dick, "Statement on Space Benefits," New York Daily News, Special Issue Commemorating the First Lunar Landing.

Haggerty, James J., "The Giant Harvest From Space - Today and Tomorrow," Air Force and Space Digest, February 1970.

Holman, Mary A., "Government Research and Development Inventions, a New Resource?," Land Economics, August 1965.

Immel, Richard A., "Space Fallout: Data Banks Containing NASA Research Fruits Help Many Companies; Research of $35 Billion Effort Available At Low Cost; Lockheed, Litton Use Files; Building a Better Oscilloscope," Wall Street Journal, March 27, 1970.

"Manned Spacecraft Center Aircraft Searches for Clues to Tuna Fish Grounds," Roundup, NASA Manned Spacecraft Center Newspaper, Houston, Texas, September 11, 1970, Vol. 9, No. 23.

"Myers Sees U.S. Approaching Critical Point in Space Budgets," Grumman Aerospace Corporation, Plane News Article (Company Newspaper), Bethpage, N.Y., Vol. 29, No. 21, November 30, 1970.

"NASA Aids in Effort to Save Corn Crop," Roundup, NASA Manned Spacecraft Center Newspaper, September 11, 1970, Vol. 9, No. 23.

Newman, Clarence, "Rover Eats High on the Hog," Newsday Newspaper, Long Island, N.Y., August 4, 1969.

"Paydirt in Moon Soil," Newsday, Long Island, N.Y. Newspaper, January 6, 1970.

"Shall We Abandon the Demands of the Future," Space Daily, Washington, D. C., May, 1970.

"Space Program Worth Cited - Direct Link with Human Survival," MSC News, Houston, Texas, Vol. 8, No. 1, January 1970 issue.

Stuhlinger, Dr. Ernst, "Why Explore Space," Marshall (NASA) Space Flight Center Newspaper, Summer 1970.

"Tests Show Water, Oxygen Available from Lunar Soil," Roundup, NASA Manned Spacecraft Center Newspaper, Houston, Texas, November 20, 1970, Vol. 10, No. 2.

"What Earthly Good is Space,? Answered in Materials for Improved Fire Safety Conference," Roundup, NASA, Manned Spacecraft Center Newspaper, Houston, Texas, Vol. 9, No. 15, November 20, 1970.

"Why Spend $20 Billion to Go to the Moon," U.S. News and World Report, An interview with the NASA Administrator, James E. Webb, July 3, 1961.

"World Reaction to Moon Flight," U.S. News and World Report, August 4, 1969.

Speeches

Biaggi, Mario, Representative, New York, Speech to the Committee on Science and Astronautics on Space Program Benefits, Spring 1970.

Frey, Jr., Louis, Representative, Florida, Speech to the Congressional Science and Astronautics Committee on Space Program Benefits, April 21, 1970.

Fulton, James G., Representative, Pennsylvania, Speech to the Canadian Club in Hamilton, Ontario, on Space Program Benefits, March 18, 1970.

Helms, J. Lynn, Vice President, Aerospace Systems Group, the Bendix Corp. Speech to the Rotary International during the University of Michigan's Sesquicentennial Celebration, The Space Program, A Citizen's Return on Investment, September 13, 1967.

Lovell, James, Captain, U.S. Navy, U.S. Astronaut, Speech to Rockhurst College, Kansas City, Missouri, on Space Program Benefits, May 14, 1970.

Low, George M. Dr., NASA Acting Administrator, Speech in Houston, Texas, The Frontiers of Space, May 2, 1970.

Lukens, D. E., Representative, Ohio, Speech to the Committee on Science and Astronautics, on Space Program Benefits, Spring 1970.

Mosher, Charles A., Representative, Ohio, Speech to the Committee on Science and Astronautics, on Space Program Benefits, April 23, 1970.

Mueller, George E. Dr., Former Associate Administrator for Manned Space Flight, Speech to the New York Society of Security Analysts, N.Y.C. on Space Program Benefits, January 28, 1969.

Paine, Thomas O., Former NASA Administrator, Speech to the National Conference on Public Administration, Miami Beach, Florida on Space Age Management and City Administration, May 20, 1969.

Pettis, Jerry L., Representative, California, Speech to the Committee on Science and Astronautics on Space Program Benefits, Spring 1970.

Roudebush, Richard L., Representative, Indiana, Speech in the 5th District of Indiana on Space Program Benefits, June 1970.

Symington, James W., Representative, Missouri, Speech to the Committee on Science and Aeronautics on Space Program Benefits, April 23, 1970.

Vander Jagt, Guy, Representative, Michigan, Speech given in the 9th District, Michigan on Space Program Benefits, 1970.

Miscellaneous

"A Survey of Space Applications ... "for the benefit of all mankind." NASA Report SP-142, Office of Technology Utilization, April 1967, Washington, D. C.

"Aeronautics and Space Report of the President to the U.S. Congress," Appendix F-1, January 1970.

Blount, Earl, Alter, Dave, Levering, W. C., Space Program Benefits, Report by North American Rockwell Corporation, Space Division, Downey, California, Report No. S-21.

"Conserving God's Good Earth," Bulletin of St. Cyril and Methodius Church, Deer Park, New York, October 11, 1970.

Crop Research Publication, ARS 34-23, Department of Agriculture.

Diethrich, Edward B., M.D., Liddicoat, John E., M.D., Schwartz, Arnold, Ph.D., Sordahl, Louis A., Ph.D., Brooks, David K., M.D. DeBakey, Michael E., M.D., "Preservation of the Human Heart," Report by Baylor College of Medicine and the Cardiovascular Research and Training Center of the Methodist Hospital, Houston, Texas, 1970.

"Federal Funds for Research, Development and Other Scientific Activities, Fiscal Years 1964, 1965 and 1966, Vol. XIV," Report of the National Science Foundation, Publication NSF 65-19, 1965.

"For the Benefit of all Mankind - A Survey of the Practical Returns From Space Investment," Report of the Committee on Science and Astronautics, U.S. House of Representatives, Ninety-First Congress Second Session, September 14, 1970.

Johnson, U. Alexis, Effect of the Space Program on America's Foreign Relations; Paper of the United States Department of State, Washington, D. C., April 3, 1970.

Lesher, Richard L., Howick, George J., "Assessing Technology Transfer," NASA Publication SP-5067, 1966, Washington, D. C.

Paine, Thomas O., Former NASA Administrator, Testimony before the Committee on Aeronautical and Space Sciences on Space Program Benefits, April 6, 1970.

"President's Economic Report to the Congress," 1970.

"Proceedings of the Winter Study on Uses of Manned Space Flight" Report of the NASA Science and Technology Advisory Committee for Manned Space Flight reporting on a conference at La Jolla, California, December 1968, NASA Report SP-196.

"The NASA Scientific and Technical Information Syste, Its Scope and Coverage," NASA Information Booklet, March 1970.

Von Braun, Wernher, The Future of Space, Proceedings of the Fourth National Conference on the Peaceful Uses of Space, Boston, Mass., April 1964, NASA Document SP 51, Washington, D. C.

"Water Facts," U.S. Department of Agriculture Report, 1957.

INDEX